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Effect of Window Over-Hang in Iraqi Building on Cooling Load

Nazar Farag Antwan*
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Abstract

A study is done on an Iraqi building to estimate and show how the use of over hang reduces the cooling load. The study shows how the effectiveness of over hang is affected by the orientation and the area (height) of the windows. This study shows that limit width of over hang on south window reduces the cooling load by (9%), and when using the over hang on the east or west window we need a large width over hang to reduce the cooling load by the same percentage. Also this study shows that using over hang and increasing the area of south windows allow us to receive a wide range of solar radiation in winter and use it in heating and lighting and the cooling load does not increase by the same percentage when using west or east windows. The results show that the using of over hang in Iraq is important especially for south windows.

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الخلاصة

تم إجراء دراسة على المباني العراقية حيث تم استخدام مواد البناء الشائعة في بناء الجدران وكان الهدف بيان و حساب تأثير استخدام الشرفة (over hang) على الحمل الحراري. الدراسة شملت مدى تأثر الحمل الحراري أثناء استخدام الشرفة و فاعلية الشرفة بتقليل الحمل الحراري عند تغير اتجاه و مساحة الشباك. بينت الدراسة انه باستخدام عرض محدود للشرفة على الجدار الجنوبي يمكن تقليل الحمل بمقدار (9%). أما عند استخدام الشرفة على الجدار الشرقي أو الغربي فإننا نحتاج إلى شرفة ذو عرض كبير نسبيا لتقليل الحمل بنفس النسبة. كما بينت الدراسة أيضا انه عند استخدام الجدار الجنوبي مع الشرفة و زيادة مساحة الشباك للحصول على الإنارة أو التدفئة مستقبلا في الشتاء فان الحمل الحراري لا يزداد بصورة كبيرة كما في الشباك الشرقي أو الغربي. أظهرت النتائج إن استخدام الشباك الجنوبي مع الشرفة ضروري جدا للابنة العراقية صيفا و شتاءاً.

Nomenclature

t	local temperature at point in the slab, C
C	specific heat, W/kg.$^{\circ}$C
θ	time, s
g	gravity acceleration, m/s^2
i,j,k	unit vectors
k	thermal conductivity, W/m.$^{\circ}$C
q	heat flux, W/m^2
X	exterior CTF coefficient W/m^2.K
Z	interior CTF coefficient W/m^2.K
Y	cross CTF coefficient W/m^2.K

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Φ	flux coefficient, dimensionless
U	overall heat transfer coefficient, $W/m^2.K$
α	thermal diffusivity, m^2/sec
V	wind speed m/s
ε	surface long wave emissivity
б	Stefan Boltizman constant 5.6×10^{-8} $W/m^2.K^4$.
F	View factor
ρ	Density, kg/m^3
CTF	Conduction transfer function
THSG	Total sensible heat gain
subscript	
s-sky	Sky
s-g	ground
in	Inside
os	Outside surface
n	Number
o	Out door

1- Introduction

Solar radiation forms the greatest single factor of cooling load in building; also, solar radiation has important effects on both heat gain and heat loss of the building. This effect depends to the great extent on both the location of the sun in the sky and the clearance of the atmosphere as well as the nature and the orientation of the building.

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Kaushik et.al [3] presented a thermal behavior of a non—air-conditioned building with walls , roof being exposed to a periodic solar radiation and atmospheric air while the inside air temperature was controlled by an isothermal mass windows and door in the walls of the room .The effects of air ventilation and infiltration of the heat capacities of the isothermal storage mass inside air and walls , roof. heat loss into the ground and the presence , absence of the window / door have been incorporated in the realistic time dependent periodic heat transfer analysis to evaluate the overall heat flux coming into the room and inside temperature. It was found that the heat fluxes through different walls have different magnitudes and phase lags with respect to the corresponding solaria temperature. The overall heat flux coming into the room as well as the room air temperature is sensitive functions of the number of air changes per hour. Stanto Shtrakov and Anton Stalov [5]. developed a numerical solution model for prediction of the thermal behaviour of passive solar system with massive.

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In this study, many kinds of windows direction and overhang size are considered to estimate the effect of their position and their area on the amount and time of peak cooling load for 21 July in Baghdad. Therefore, are can see the best window overhang in summer to make the peak cooling load of the building as small as possible or to shift it to time where the building is not used. Transient heat transfer through walls, roofs is estimated, so using Z-transformation method with conduction transfer function and using computer program to estimate the cooling load for experimented building in Baghdad for (24 hours) with many kinds of windows and over hangs.

2-Theory

The heat flux at the *j*th exterior surface for time θ is given by[4]:

$$q''_{conduction,out,j,q} = -Y_o t_{is,j,q} - \sum_{n=1}^{Ny} Y_n t_{is,j,q-nd} + X_o t_{os,j,q} + \sum_{n=1}^{Nx} X_n t_{os,j,q-nd} + \sum_{n=1}^{Nq} \Phi_n q''_{conduction,out,j,q-nd} \quad (1)$$

and the heat flux at the *j*th interior surface for time θ is given by

$$q''_{conduction,in,j,q} = -Z_o t_{is,j,q} - \sum_{n=1}^{Nz} Z_n t_{is,j,q-nd} + Y_o t_{os,j,q} + \sum_{n=1}^{Ny} Y_n t_{os,j,q-nd} + \sum_{n=1}^{Nq} \Phi_n q''_{conduction,in,j,q-nd} \quad - (2)$$

where:

$q''_{condition,\ out,\ j,\theta}$ =heat flux at exterior surface, W/m^2

$q''_{condition,\ in,\ j,\theta}$ =heat flux at interior surface, W/m^2

Yn=cross CTF coefficient, W/(m^2-K)

Xn=exterior CTF coefficient, W/(m^2-K)

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$t_{is,j,\theta}$=interior surface temperature, C

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The CTF constants are estimated using method of [6] , which is putted in computer program in [4].

Absorbed solar heat gain is calculated as [4]:

$$q''_{solar,out,j,q} = aG_t \quad ---(3)$$

α = solar absorptivity of the surface, dimensionless

Gt=total solar irradiation incident on the surface, W/m^2

Convection to exterior surfaces may be represented with a range of models, all of which involve the use of a convection coefficient [4] :

$$q''_{convection,in,j,q} = h_c(t_o - t_{os,j,q}) \quad (4)$$

The exterior surfaces radiate to and receive heat and from the surrounding ground, vegetation, parking lots, sidewalls, other buildings, and the sky [4].

$$q''_{radiation,out,j,q} = h_{r,g}(t_g - t_{os,j,q}) + h_{r,sky}(t_{sky} - t_{os,j,q}) \quad \text{-- (5)}$$

where:

$$F_{s-g} = \frac{1-\cos a}{2}$$

$$F_{s-sky} = \frac{1+\cos a}{2}$$

And

$$h_{r,g} = es\left[\frac{F_{s-g}(t_g^4 - t_{os,j,q}^4)}{t_g - t_{os,j,q}}\right]$$

$$h_{r,sky} = es\left[\frac{F_{s-sky}(t_{sky}^4 - t_{os,j,q}^4)}{t_{sky} - t_{os,j,q}}\right]$$

The transmitted direct (beam) [4]

$$\dot{q}_{direct} = A_{SL}(SC)G_D \sum_{j=0}^{5} tj[\cos q]^j \quad (6)$$

And the diffuse radiation

$$\dot{q}_{diffuse} = A(SC)2G_d \sum_{j=0}^{5} \frac{t_j}{j+2} \quad \text{----(7)}$$

For inside wall convection

$$q''_{convection,in,j,q} = h_c(t_{is,j,q} - t_i) \quad (8)$$

Radiation between surfaces in an enclosure is a fairly well-understood process,

The area of the fictitious if face that exchanges radiation with the *j*th surface in the room is the sum of the other areas of the other surfaces:[4]

$$A_{f,j} = \sum_{i=1}^{N} A_i(1-d_{ij}) \quad \text{----(9)}$$

where:

N= number of surfaces in the room

A_i = area of the *i*th surface, ft^2 or m^2

d_{ij} = Kronecker delta

$$= \begin{cases} 1 & if \quad i = j \\ 0 & if \quad i \neq j \end{cases}$$

$$q''_{radiation-surf,in,j,q} = h_{r,j}(t_j - t_{f,j}) \quad (10)$$

The net radiation leaving each surface is then given by;

$$q''_{radiation-surf,in,j,q} = h_{r,j}(t_j - t_{f,j}) - q''_{balance} \quad \text{-(11)}$$

Then it can say [4]

$$\sum_{j=1}^{N} Ajq''_{convection,in,j,q} + \dot{q}_{infltration,\theta} + \dot{q}_{system,\theta} + \dot{q}_{internal,conv,\theta} = 0 \quad \text{--(12)}$$

2-10-Problem Formulation

Fig. (11) shows the problem under study and Tables (1) and (2) show the specification.

3-Results And Discussion

As shown from Figs. (1) to (4) the shape of load distribution at (24) hours is not affected by the area of the windows, but the cooling load quantity does. These curves show that the window at the east makes the peak load at 1600 hour while the west window make the peak load at 2400 hour because the time of entering the radiation of the sun to the building is different and the outdoor temper is also different. This shape of cooling load distribution will change only when the walls, roof, place of the building, and the time of estimating the cooling load change. From Fig.(5) we can see that the increasing of the window area causes more increasing of the cooling load when using east or west windows compared with the south or north windows. Fig. (6) shows how the over hang on the south window reduces the cooling load for limit width of over hang and any increasing in the width of over hang does affect the cooling load. Moreover, from the same figure it can seen that for the east and west windows the increasing in over hang width reduces the cooling load and we need very large width over hang compared with the south window to reach the same cooling load. The reason for these results is the sun radiation is nearly vertical in July. Fig. (7) shows how the increasing in widow area increases the cooling load. Therefore, from the Figure we can see that when we need a large area of window for lighting perhaps, the most effective windows that give large area and less cooling load are the north and south windows. Fig. (8) shows how the cooling load increase when using over hang of (0.5) meters width with increasing of window height. Figs. (9) and (10) show that when using (1.5 and 2) meters window height any increase in over hang from (0.5) meters does not affect the cooling load for south and north windows, but the east and the west windows effect is clear.

4- Conclusions

From this study it can seen that for Iraqi building:-

1. The south window is the best in summer and winter, because its effect on cooling load in summer is small over hang respectively. In addition, in winter this window will transmit a large amount of sun radiation.
2. The north window is very suitable in summer and transmits only the diffused radiation. Nevertheless, in winter this window fails in transmitting direct solar radiation for heating.
3. The east and west windows are bad choice because they bring large amount of cooling load compared with the south and north windows and the use of over hang does not treat the problem.
4. The over hang is much effective way for south windows in Iraqi building for reducing the cooling load.

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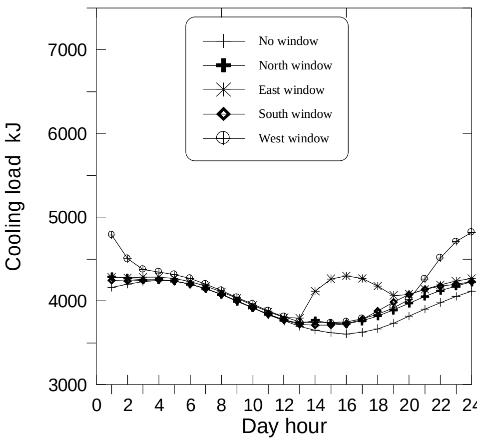


Figure (1) Cooling load for different window directions with (2.25)squar meters window area

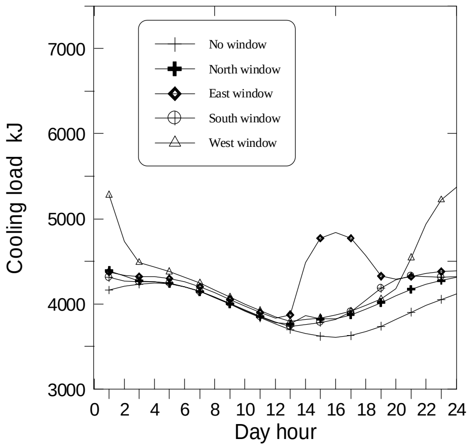


Figure (2) Cooling load for different window directions with (4)squar meters window area

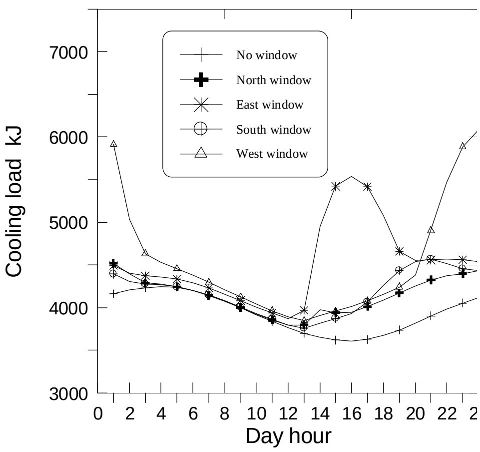


Figure (3) Cooling load for different window directions with (6.25)squar meters window area

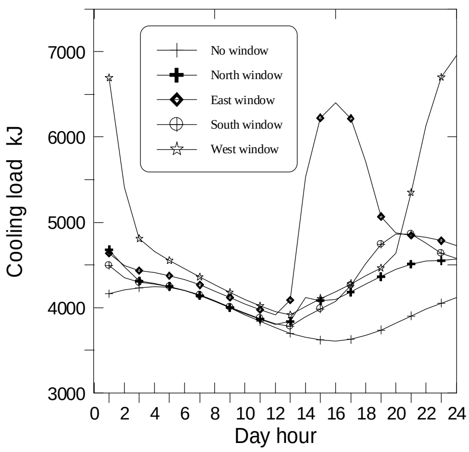


Figure (4) Cooling load for different window directions with (9)squar meters window area

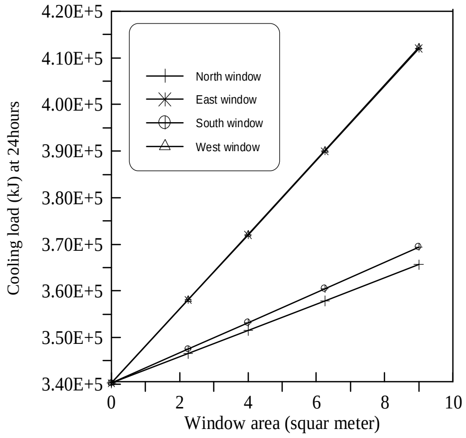


Figure (5) Effect of window area increase on cooling load for different facing window

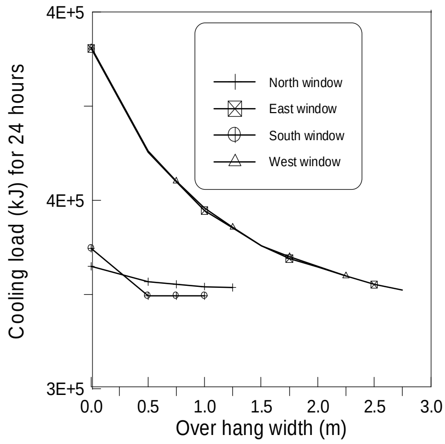


Figure (6) Effect of over hang width on cooling load for (2.25) squar meter at different directions

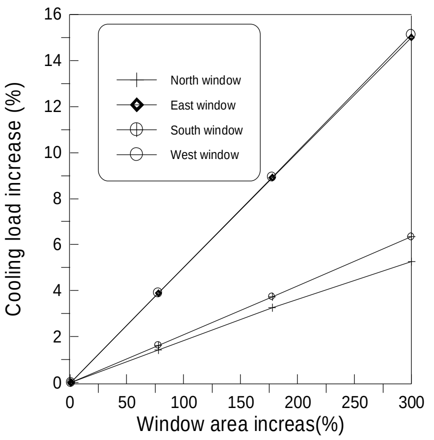


Figure (7) Percentage of cooling load incrasing with percentage of window area increasing

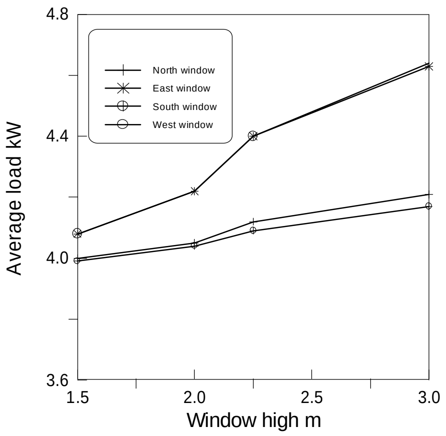


Figure (8) Cooling load increase with increasing window high when using over hang width 0.5 meter

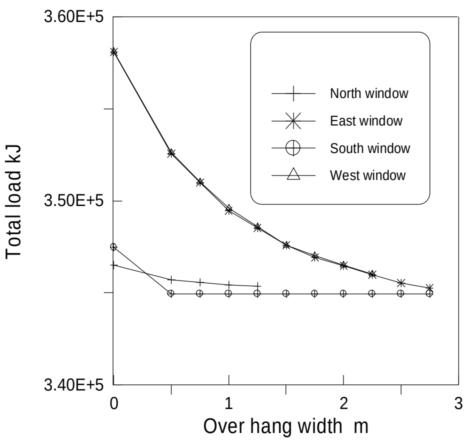


Figure (9) The effect of over hang width on cooling load when using window with 1.5 m high

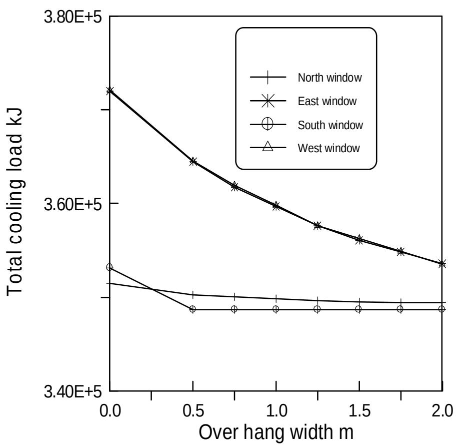
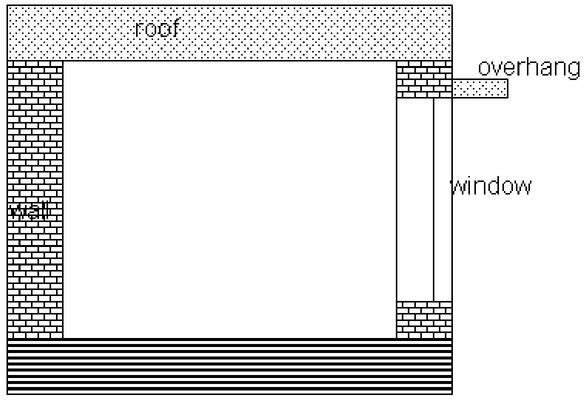


Figure (10) The effect of over hang width on cooling load when using window with 2.0 m high



Figure(11)

Table (1) Out door and indoor design conditions for room located in Iraq-Baghdad	
City	Baghdad
Latitude	33 degree
Longitude	44
Out door dry bulb temperature	45 ^oC
Out door wet bulb temperature	23.2 ^oC
Daily range	18.7
Ground temperature	22.2 ^oC
Clearness factor	1
Indoor dry bulb temperature	25 ^oC
month	July
day	21
Wind direction	315 degree clockwise from north
Wind speed	3.3 m/s
Room dimension	4*4*3 m
Area of window (located in the eastern wall)	3*3 m

Table (2)
Iraqi walls and roof specifications

Wall	gypsum ٢٠ mm	brick ٢٤٠mm	low density concrete ٢٠mm			
Roof	gypsum ٢٠ mm	high density concrete ١٥٠mm	felt and member ٢٠mm	clay ١٠٠mm	sand ٤٠mm	concrete block ٤٠mm

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and the heat flux at the *j*th interior surface for time θ is given by

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α = solar absorptivity of the surface, dimensionless

Gt=total solar irradiation incident on the surface, W/m^2

Convection to exterior surfaces may be represented with a range of models, all of which involve the use of a convection coefficient [4] :

$$q''_{convection,in,j,q} = h_c(t_o - t_{os,j,q}) \quad (4)$$

The exterior surfaces radiate to and receive heat and from the surrounding ground, vegetation, parking lots, sidewalls, other buildings, and the sky [4].

$$q''_{radiation,out,j,q} = h_{r,g}(t_g - t_{os,j,q}) + h_{r,sky}(t_{sky} - t_{os,j,q}) \quad \text{-- (5)}$$

where:

$$F_{s-g} = \frac{1-\cos a}{2}$$

$$F_{s-sky} = \frac{1+\cos a}{2}$$

And

$$h_{r,g} = es\left[\frac{F_{s-g}(t_g^4 - t_{os,j,q}^4)}{t_g - t_{os,j,q}}\right]$$

$$h_{r,sky} = es\left[\frac{F_{s-sky}(t_{sky}^4 - t_{os,j,q}^4)}{t_{sky} - t_{os,j,q}}\right]$$

The transmitted direct (beam) [4]

$$\dot{q}_{direct} = A_{SL}(SC)G_D \sum_{j=0}^{5} tj[\cos q]^j \quad (6)$$

And the diffuse radiation

$$\dot{q}_{diffuse} = A(SC)2G_d \sum_{j=0}^{5} \frac{t_j}{j+2} \quad \text{----(7)}$$

For inside wall convection

$$q''_{convection,in,j,q} = h_c(t_{is,j,q} - t_i) \quad (8)$$

2-10-<u>Problem Formulation</u>

Fig. (11) shows the problem under study and Tables (1) and (2) show the specification.

3-<u>Results And Discussion</u>

As shown from Figs. (1) to (4) the shape of load distribution at (24) hours is not affected by the area of the windows, but the cooling load quantity does. These curves show that the window at the east makes the peak load at 1600 hour while the west window make the peak load at 2400 hour because the time of entering the radiation of the sun to the building is different and the outdoor temper is also different. This shape of cooling load distribution will change only when the walls, roof, place of the building, and the time of estimating the cooling load change. From Fig.(5) we can see that the increasing of the window area causes more increasing of the cooling load when using east or west windows compared with the south or north windows. Fig. (6) shows how the over hang on the south window reduces the cooling load for limit width of over hang and any increasing in the width of over hang does affect the cooling load. Moreover, from the same figure it

Radiation between surfaces in an enclosure is a fairly well-understood process,

The area of the fictitious if face that exchanges radiation with the *j*th surface in the room is the sum of the other areas of the other surfaces:[4]

$$A_{f,j} = \sum_{i=1}^{N} A_i(1-d_{ij}) \quad \text{----(9)}$$

where:

N= number of surfaces in the room

A_i = area of the *i*th surface, ft^2 or m^2

d_{ij} = Kronecker delta $= \begin{cases} 1 & if \quad i = j \\ 0 & if \quad i \neq j \end{cases}$

$$q''_{radiation-surf,in,j,q} = h_{r,j}(t_j - t_{f,j}) \quad (10)$$

The net radiation leaving each surface is then given by;

$$q''_{radiation-surf,in,j,q} = h_{r,j}(t_j - t_{f,j}) - q''_{balance} \quad \text{-(11)}$$

Then it can say [4]

$$\sum_{j=1}^{N} Ajq''_{convection,in,j,q} + \dot{q}_{infltration,\theta} + \dot{q}_{system,\theta} + \dot{q}_{internal,conv,\theta} = 0 \quad \text{--(12)}$$

can seen that for the east and west windows the increasing in over hang width reduces the cooling load and we need very large width over hang compared with the south window to reach the same cooling load. The reason for these results is the sun radiation is nearly vertical in July. Fig. (7) shows how the increasing in widow area increases the cooling load. Therefore, from the Figure we can see that when we need a large area of window for lighting perhaps, the most effective windows that give large area and less cooling load are the north and south windows. Fig. (8) shows how the cooling load increase when using over hang of (0.5) meters width with increasing of window height. Figs. (9) and (10) show that when using (1.5 and 2) meters window height any increase in over hang from (0.5) meters does not affect the cooling load for south and north windows, but the east and the west windows effect is clear.

4- Conclusions

From this study it can seen that for Iraqi building:-

1. The south window is the best in summer and winter, because its effect on cooling load in summer is small over hang respectively. In addition, in winter this window will transmit a large amount of sun radiation.
2. The north window is very suitable in summer and transmits only the diffused radiation. Nevertheless, in winter this window fails in transmitting direct solar radiation for heating.
3. The east and west windows are bad choice because they bring large amount of cooling load compared with the south and north windows and the use of over hang does not treat the problem.
4. The over hang is much effective way for south windows in Iraqi building for reducing the cooling load.

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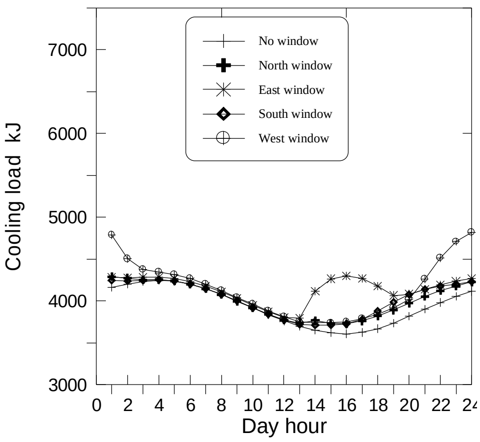


Figure (1) Cooling load for different window directions with (2.25)squar meters window area

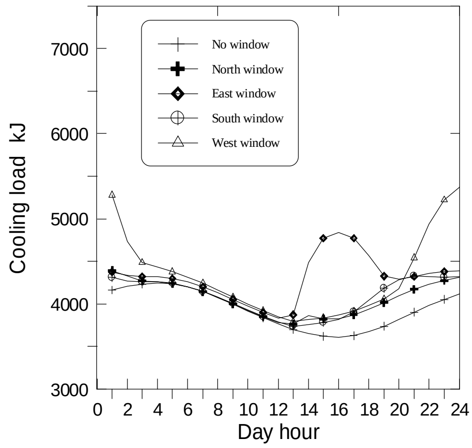


Figure (2) Cooling load for different window directions with (4)squar meters window area

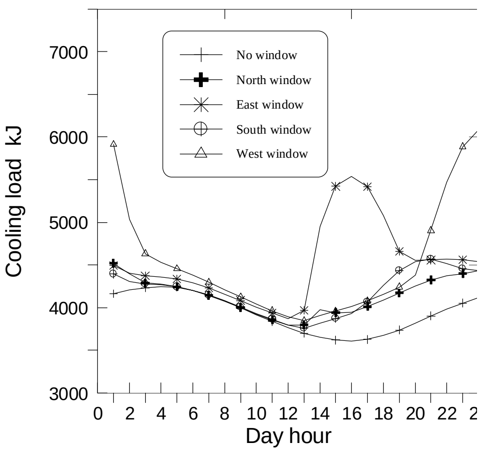


Figure (3) Cooling load for different window directions with (6.25)squar meters window area

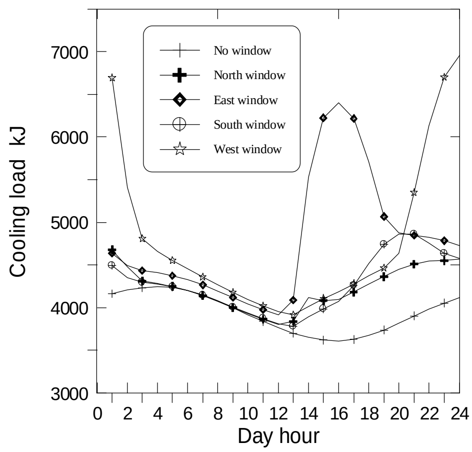


Figure (4) Cooling load for different window directions with (9)squar meters window area

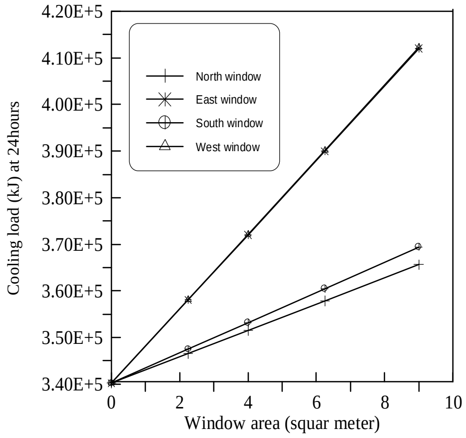


Figure (5) Effect of window area increase on cooling load for different facing window

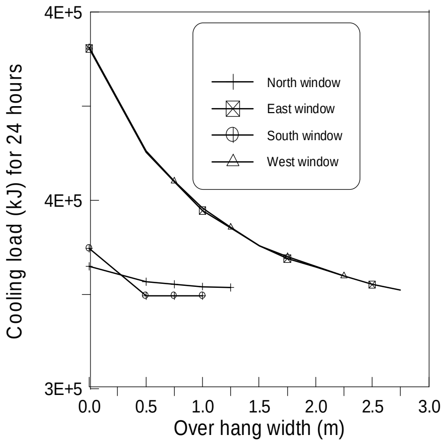


Figure (6) Effect of over hang width on cooling load for (2.25) squar meter at different directions

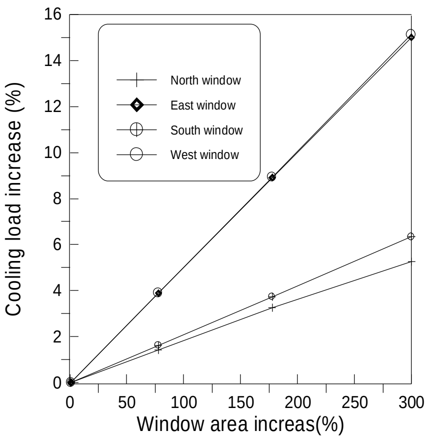


Figure (7) Percentage of cooling load incrasing with percentage of window area increasing

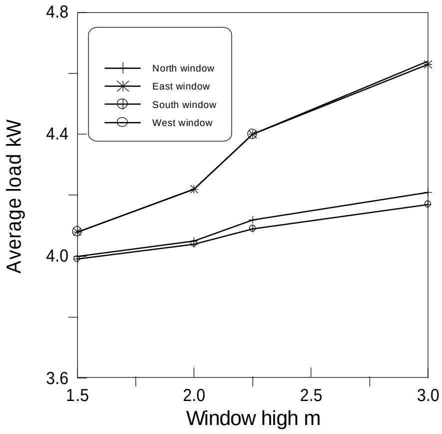


Figure (8) Cooling load increase with increasing window high when using over hang width 0.5 meter

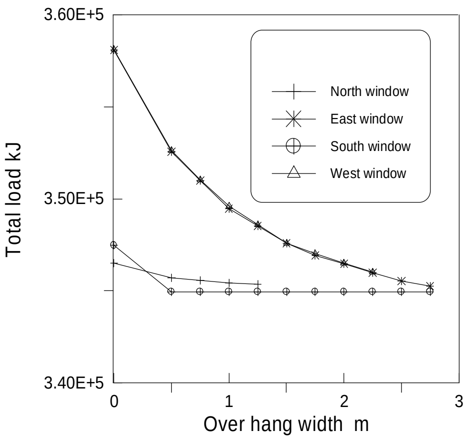


Figure (9) The effect of over hang width on cooling load when using window with 1.5 m high

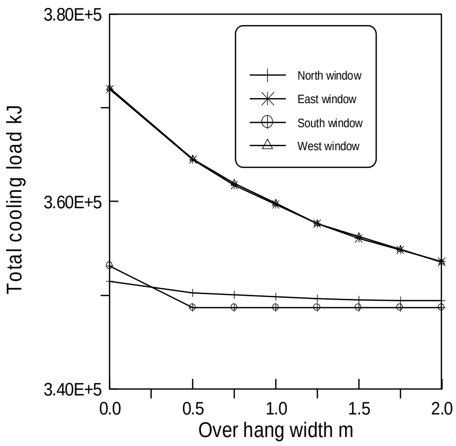
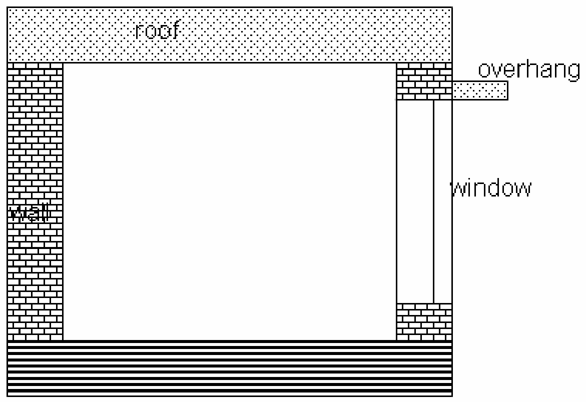


Figure (10) The effect of over hang width on cooling load when using window with 2.0 m high



Figure(11)

Table (1) Out door and indoor design conditions for room located in Iraq-Baghdad	
City	Baghdad
Latitude	33 degree
Longitude	44
Out door dry bulb temperature	45 ^{o}C
Out door wet bulb temperature	23.2 ^{o}C
Daily range	18.7
Ground temperature	22.2 ^{o}C
Clearness factor	1
Indoor dry bulb temperature	25 ^{o}C
month	July
day	21
Wind direction	315 degree clockwise from north
Wind speed	3.3 m/s
Room dimension	4*4*3 m
Area of window (located in the eastern wall)	3*3 m

Table (2)
Iraqi walls and roof specifications

Wall	gypsum 20 mm	brick 240mm	low density concrete 20mm			
Roof	gypsum 20 mm	high density concrete 150mm	felt and member 20mm	clay 100mm	sand 40mm	concrete block 40mm