International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

The Investigation of the Effecting of Solar Radiation on Housing and Building Facades

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Abstract**—*The present work investigates solair temperatures in Iraq and the level of confrontation imposed upon building facades, and presenting a set of nomographs to easily calculate it. In hot dry climates, the building envelope embraces. protects and shields the residents against solar radiation domination and hostile, very hot air Acquiring suitable properties and adequate thermal resistance will minimize discomfort and reduce energy consumption, hence securing the conservation of energy Building thermal regulation standards all ever the world we repeatedly polished to cope and encounter the surrounding climate. It is worthless to relay and depend only upon registered air temperature and neglecting the heating effect of the solar radiation opposing and confronting buildings. Within this procedure.*

Keywords**—*sol-air temperature, overall resistance, energy conservation.*

I. INTRODUCTION

In hot dry climates die building envelope protects the residences against external chromic factors, of which the air temperature constitutes a large part. The overall resistance of the external envelope is the first line of defense of dwellings whatever its form, orientation or configuration with the near by building. That is why all over the world, realizing the meaning of energy and it's cost consumption, specially after the oil crisis embargo in the early 1970's has been progressively increasing the overall resistance of external walls and roofs of dwellings with appropriate properties in order to counteract a wide range of external climatic conditions and to minimize discomfort and reduce energy consumption.

The need to conserve energy has become extremely apparent, pre to that energy was relatively cheap and energy conservation was not in perspective. This is clear in Fig. 1A. highlighting the continuous changes in the English and Welsh Building Thermal Regulations Standards. i.e. lowering the coefficient of Heat Transfer and competing the adopted levels with those in Europe and the Middle east. Fig. 1B The standards throughout Europe for both exposed walls and roofs are quite close [1]. Iraq has recently put forward a draft code for energy efficient buildings with high expectations of implementing it. The Iraqi thermal regulations for dwellings are quite close to those of the state of Kuwait but much higher than those of Turkey and far off those of Europe, but quite close to the British regulations in the in the late 70s. Fig. 1A and B. In Iraq, enforcing thermal regulations is a tremendous step towards mandating higher thermal performance for buildings, which will eventually yield high revenues on energy consumption for both the building users and the state.

Understanding the external temperatures confronting buildings is of extreme importance, in order to be avoided and tackled. An example to illustrate this; is that in a cold climate such as England [2], where the air temperature in the month of July according to Kew and Cardington stations reaches In a maximum of 27^{o}C at 14.00 hrs. And in direct sunlight the sol-air temperature on a horizontal dark surface reaches over 50^{o}C and nearly 60^{o}C on a western elevation, Fig. 1C. England is an example of a country in the cold part of the Northern hemisphere in which the levels of external air temperatures confronted with in summer with solar exposure on a horizontal surface exceed the air temperature by an average of 71% throughout the day and double at noon. While on a Western vertical orientation it exceeds it by an average: of 53% throughout the day and above double at mid afternoon.

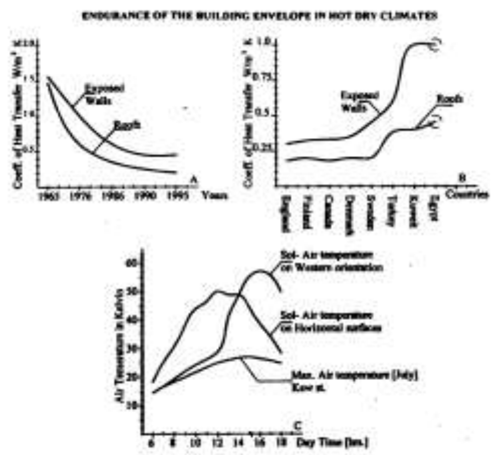

Fig. 1. [A] English and Welsh building thermal regulation standards [1995].
[B] Building thermal regulations throughout Europe and Middle East.
[C] Air and sol-air temps. for Horizontal and Western facades, 52°N Kew st.

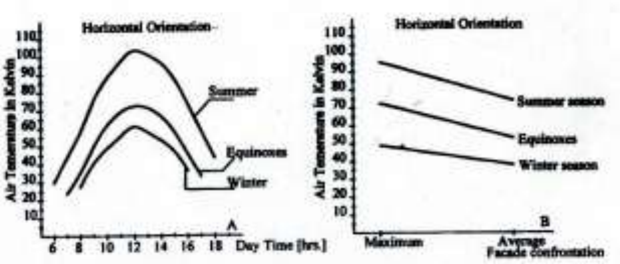

Fig. 2. [A] Daily sol-air temperature on horizontal surfaces, 30° N.
[B] Maximum reached and average sol-air temperatures on horizontal surfaces.

What are the levels of air temperatures that confront buildings in Iraq which is located in a hot dry part of the world, and hence affects all its orientations? This is what triggered the researcher to investigate the complicated topic

Abbas Zghair Salman, "The investigation of the effecting of solar radiation on housing and building facades" *International Research Journal of Advanced Engineering and Science*, Volume 3, Issue 1, pp. 274-278, 2018.

and try to formulae, design and put forward a simple procedure to easily calculate the actual external air temperature with sunlight exposure in Iraq, to enable confronting it with the appropriate protection.

II. SOL- AIR TEMPERATURES

In hot dry climates the building fabric is not only confronted with extremely high external temperatures but also with a high discomfortable diurnal range not just between the inside and outside air temperature, but between an inside air and outside sol-air temperature, which is a combination of the air temperature and the heating effect caused by the direct, diffused and reflected solar radiation which in turn is transmitted through the building envelope "sol-air temperature range"[3].

In order to define the actual temperatures a building external fabric is confronted with, which is needed to calculate a dependable time lag required by the external envelope surfaces "flat and/or vertical", the solar radiation heating effect on the air temperature using sol-air temperature concept should be considered [4]. This will enable the definition of the actual values of sol-air temperatures the building confronts, The sol-air temperature acting on the external building envelope will greatly depend upon the absorptivity of the external surface of the envelope which in turn depends upon the finishing color and its texture being rough or smooth. It will also depend upon the external surface conductance "W/m^2degC" of that thin layer of air separating the envelope from the surrounding air which in turn is a function of wind speed, that it is always less near the ground than higher up [5]

III. THE MODEL

The form of the dwelling investigated was a simple low rise cubic form with its sides facing4w four major orientations [N, E, W and S] with complete solar exposure throughout the day. The external surface color of die walls was reddish facing bricks, the roof was finished in cement tiles and with the prevailing pollution conditions both the horizontal and vertical surfaces get darker with raised absorptivity. The vertical facades and roof were chosen of dark calm due to the fact that the majority of buildings whether light or dark in color end in almost dark grayish polluted color. The window apertures were of aluminum 6mm regular glass taken on each side of the dwelling.

The sol-air temperature was calculated throughout the day for summer the equinoxes and winter considering only the direct effect of the solar radiation not that reflected off the surrounding landscape and near by buildings. It was calculated for the five different orientations using the climatological normal provided by the Building Draft Code and the Middle east Meteorological Authority [6].

On Horizontal surfaces [flat roofs] the so]-air temperature reached up to an average of 74°C, 53°C and 38°C throughout the day and to a maximum of 95°C, 73°C and 50°C at midday at summer, equinoxes and winter seasons respectively. An average increase of the order of 210% and 250% to the registered air temperatures through out the year, for the daily and at midday air temperatures respectively, was observed Fig. 2A, B and Fig.6.

On the Eastern orientation, the sol-air temperature reached up to an average of 54°C, 44°C and 33°C throughout the morning till just before noon and a maximum of 63°C, 52°C and 40°C at mid morning at summer, equinoxes and winter seasons respectively. An average increase of 200% and 263% to the registered air temperatures through out the year, for the daily and mid morning air temperatures respectively, was observed Fig, 3A, C and Fig. 5.

On the Western orientation, the sol-air temperature reached up to an average of 63°C, 49°C and 38°C through out the afternoon till just before sunset and a maximum of 79°C, 61°C and 46°C at mid afternoon at summer equinoxes and winter seasons respectively. An average increase of 175% and 210% to the registered air temperatures through -out the year, for the afternoon and mid afternoon or temperatures; respectively, was also observed Fig. 3A. B and Fig. 5A [7].

On the Northern facade, in the summer season sol air temperature reached to an average of 38oC throughout the day with solar exposure and a maximum of 32°C and 47°C at early mornings and late alterations. An increase of 110% throughout the day and a maximum of 140%, 125% increase in early morning and late after noon, Fig. 4 A and B. As for the rest of the seasons, the Northern facade is completely obscured from direct solar radiation.

On the Southern facade, sol-air temperatures exceeded all other orientations both the horizontal and vertical facades. It reached to an increase of 110% throughout the day and a maximum of 140%, 125% increase in early morning and late after noon, Fig. 4 A and B. As for the rest of the seasons, the Northern facade is completely obscured from direct solar radiation.

On the Southern facade, sol-air temperatures exceeded all other orientations both the horizontal and vertical facades. It reached to an average of 37°C, 40°C and 48°C through out the day and a maximum of 46°C, 53°C and 65°C at mid day for the summer, equinoxes and winter seasons respectively. An average increase of 110%, 170% and 250% through out the day and a maximum of 113%. 290% and 300% at mid day, was observed Fig. 4 A. B and Fig. 5B [8].

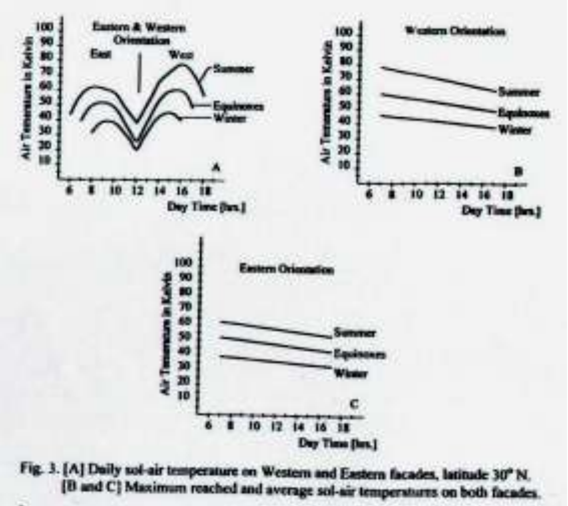

Fig. 3. [A] Daily sol-air temperature on Western and Eastern facades, latitude 30° N. [B and C] Maximum reached and average sol-air temperatures on both facades.

Abbas Zghair Salman, "The investigation of the effecting of solar radiation on housing and building facades" *International Research Journal of Advanced Engineering and Science*, Volume 3, Issue 1, pp. 274-278, 2018.

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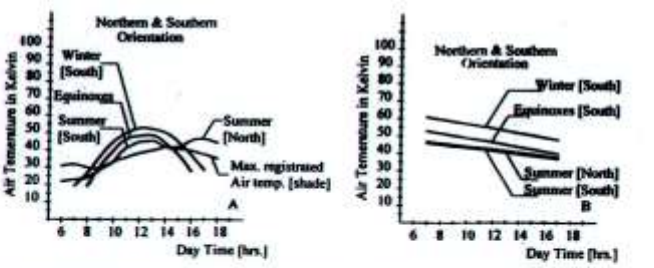

Fig. 4. [A] Daily sol-air temperature on the South and North facades, latitude 30° N. [B] Maximum reached and average sol-air temperatures on both facades.

The Southern facade faced higher levels of solar radiation in winter rather than summer that hardly received a speck of direct solar radiation [the average increase in temperature throughout the day in the summer season on the southern facade was exactly the same as the northern facade]. This also applies to the extreme temperatures reached at mid-day on the Southern facade and in the late afternoon on the Northern facade. There was hardly any difference in temperature between both facades.

Sol-air temperatures were extremely high on horizontal flat surfaces reaching to a temperature of 96°C, the eastern facade faced temperatures reaching to 63°C, while on the western it was 79°C. Extremely high temperatures building facades in hot dry climates are confronting. As for glass apertures, it greatly depend upon the Pipe of glass and its thermal specifications; e.g. using regular ordinary 6mm single glass windows the temperatures confronted would be wound 25% of sol air temperatures confronted by the opaque facades of the building [9,10].

IV. Heat Gain Through The Building Envelope

Confronted with such high temperatures the amount of bent gain through the building envelope was further investigated and calculated employing the extreme sol-air temperature reached at different orientations for a number of different wall and roof cross sections that are commonly and frequently used in Iraq, namely:

- Wall 1: a 12 cm brick wall with 2 cm cement piaster finish on the internal mid external surfaces.
- Wall 2: a 25 cm brick wall with 2 cut cement plaster finish on the internal and external surfaces.
- Wall 3: same as Wall 2 with 2 cm cement mortar and 2 cm marble facing external surfaces.
- Wall 4: same as Wall 2 with 2 cm cement mortar and 3 cm lime facing stone on the external surfaces.
- Wall 5: a cavity wall of two 12 cm brick wall skins with 2 cm cement plaster finish on the internal and external surfaces and with 4 cm air cavity in between.
- Wall 6, Wall 7. Wall 8, Wall 9 and Wall 10: the same as Wall 5, but with 1, 2, 3, 4 and 5 cm polystyrene foam or rice straw blanket in between.
- Roof 1: a 12 cm reinforced concrete slap, 2 cut insulating bitumen, 7 cm sloping concrete. 5 cm sand, 2 cm cement tiles with an internal layer of cement plaster.
- Roof 2: similar to roof I but with a layer of 20 cm reinforced concrete flat slap.
- Roof 3: similar to roof I but with a layer of 20 cars hollow blocks covered with 5 cm reinforced concrete.

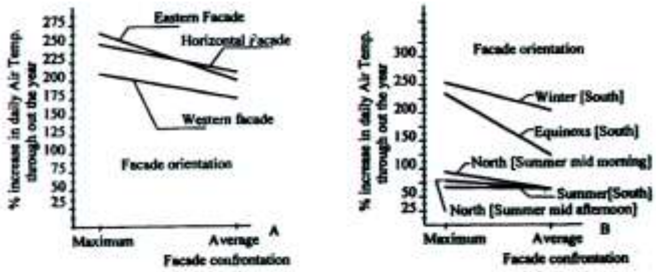

Fig. 5. A and B Maximum and average % increase to the registered air temperatures.

Each wall and roof cross section bad its own overall resistance and its reciprocal the overall coefficient of heat transfer, Fig, 6A and B. The richer the treatment of the cross section the greater was its resistance.

This was further seen in the amount of heat gain through the different wall and roof cross sections chosen. The internal comfortable air temperature was assumed to be 20°C: the heat gain through the different horizontal and vertical facades was calculated per square meter applying the highest sol-air temperature faced by each facade for all the different cross sections [11, 12].

In the summer season, the amount of heat gain through both the horizontal and Western facades were the highest, the Western facade exceeded the horizontal by almost an average of 25% throughout the exposed period. The amount of heat gain through wall 1 and roof 1 that we most commonly practiced throughout Iraq was 147 and 127 w/m^2.

This means that one fifth and one sixth horse power of an A/C unit is approximately required to compensate the heat gain from every square meter of wall and roof respectively. Fig. 7A. As for the Eastern facade the amount of heat gain was also quite high 107 w/m^2 that would approximately require one seventh horse power of an A/C unit to compensate the beat gain.

The Southern facade was almost an exact duplicate of the Northern facade, the amount of beat gain was also moderately high, 65 wears per square meter dial would require approximately oat twelfth horse power of an A/C unit to compensate the heat gain for die same wall am section, Fig. 7A [13, 14].

During the equinoxes the Western facade was found to be the worst affected; followed directly by horizontal surfaces with an amount of heat gain through both of 100 and 90 %. The Southern facade encounters mare solar radiation than in summer and coincides with the eastern facade with an amount of heat gain of 80 w/m^2 the northern façade is completely in shade affected only by the external air temperature, Fig. 7B.

In winter, the Southern facade exceeded all other vertical and horizontal facades with an amount of heat gain of 100w/m2. All the other facades relatively fell back, the horizontal surface coincides approximately with the Eastern façade, and the Western was close but a bit higher with an amount of heat gain of 50 and 65w/m^2 respectively. The Northern facade remained in complete shade. Fig. 7C [15].

This would be due to the lowering of the solar altitude angle of the sun leading to a direct increase on the Southern facade in solar hours and intensity and a decrease in

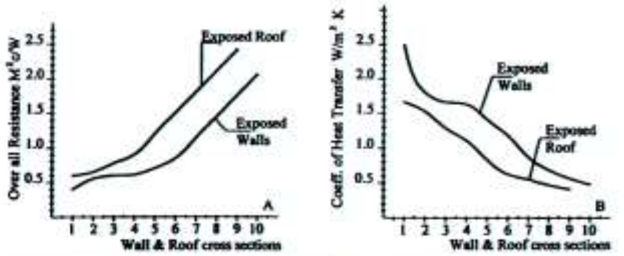

Fig. 6. A and B Resistance and coefficient of heat transfer for cross sections chosen.

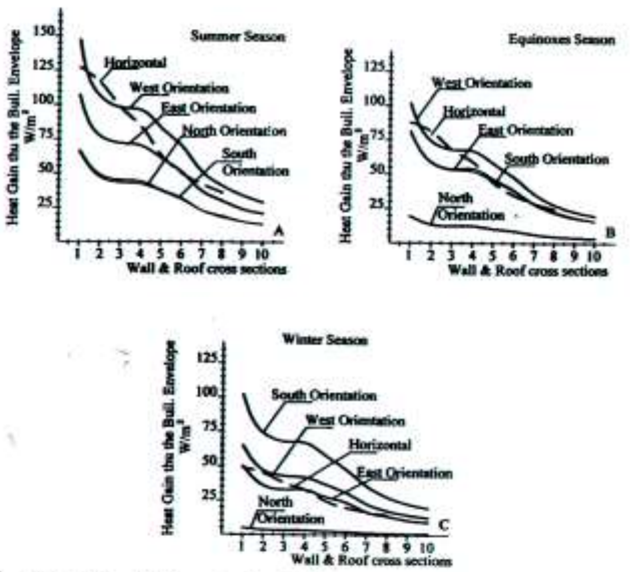

Fig. 7. A, B and C Heat gain through different orientations throughout the year.

Hours and intensity on all the other facades. And, that is the reason a Southern facade is considered to be a winter resort. Where the heat from the sun compensates the cold lower temperatures of the air.

V. THE PROPOSED DESIGN CHARTS

In order to easily acquire the true and actual outside air temperature building facades are confronted with, and hence facilitate facing and encountering it with the proper magnitude of protection. A relation was deducted, designed and developed to tie the variables that are involved in the build tip of the sol air temperature. The direct solar intensity impact upon building facades the absorbtivity of the external surface of the building facade and its surface conductance, which is a function to wind speed.

The range of absorbtivity of external facades applied were for a number of finishing materials [1] that ranged from an average of: 85% for polluted dark gray, 75% for reddish bricks/stone or course cement plaster, 55% dull brownish yellow bricks /stone or concrete slab/tiles, 40% cream bricks or smooth plaster and 25% for white paint - for vertical and horizontal facades. An additional percentage can be added for each range to account for the excess settling of air pollution existence [16].

The design monographs charts were formulated, developed and designed for summer, equinoxes and winter seasons for both horizontal and vertical facades. The vertical surfaces were divided into two categories; one representing the Eastern and Western facades and the other, the Southern and Northern facades, to be easily mastered and dealt with, Fig. 8 A,B and C.

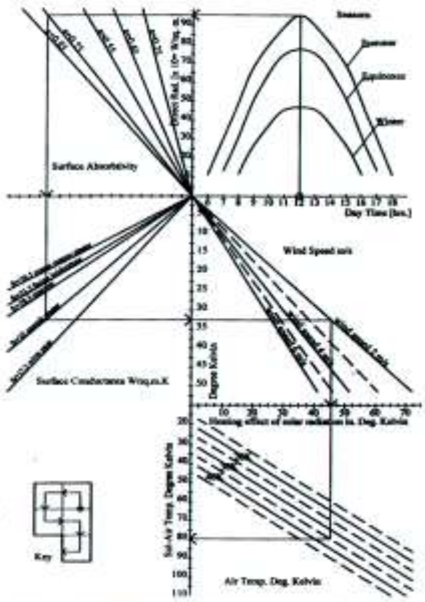

Fig. 8. A Sol-air temperature nomograph for horizontal surfaces, 30° N.
Designed and developed by the author.

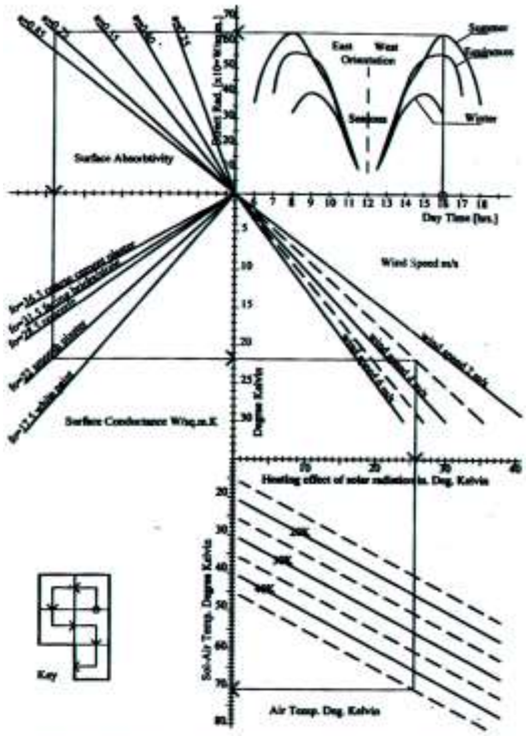

Fig. 8. B Sol-air temperature nomograph for western and eastern facades. 30° N.
Designed and developed by the author

International Research Journal of Advanced Engineering and Science
ISSN (Online): 2455-9024

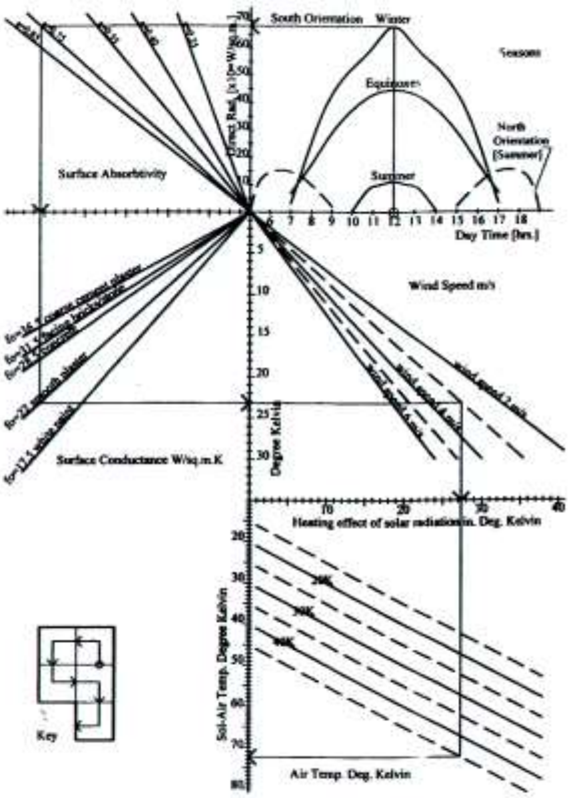

Fig. 8. C Sol-air temperature nomograph for southern and northern facades. 10° N. Designed and developed by the author

The procedure of using the different charts is simply the same; namely: starting from the horizontal scale at the upper right corner for the required time of day, moving upwards till intersecting the required orientation and season.

Read the direct sol-air impact imposed upon the facade under investigation in watt per square meter on the vertical scale.

Continue to the left comer till intersecting with the appropriate surface absorptivity or interpolate in-between.

Move downwards till intersecting with the surface conductance of the material appropriate to the facade under treatment or interpolate in-between.

Read the solar radiation heating effect upon the air temperature in degree Kelvin at a wind speed of 4 m/s on the vertical scale

Continue towards the right comer till intersecting with the appropriate wind speed for the site or location or -interpolate in between".

Then move downward till intersecting with the air temperature of the location and read the sol-air temperature confronted by the facade under investigation in degree K on the vertical scale, Fig. 8A, B and C

VI. CONCLUSION

The extremely high temperatures building facades in hot dry climates are confronting make the appropriate confrontation at the design stage a necessity that should be mandated and enforced by legislation, design codes and building regulations. The return revenue would be quite high in energy conservation for both the occupants and the state authorities. local and central.

The subject treated and discoursed in this paper justifies the recommendations to designers and architects to strive in upgrading the overall resistance of the external building envelope to shield and guard the occupants [specially the low income groups whose scarce resources wouldn't allow them to achieve acceptable comfort standards] against external severe sol-air temperatures.

The design task, to reach better external envelope, is facilitated by the set of proposed design charts [monographs] which enable accurate determination of sol-air temperatures for a variety of settings in Iraqi cities.

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