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Comparative study between dynamic transient and degree-hours methods to estimate heating and cooling loads of building's wall

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Abstract

In this paper, dynamic transient method and conventional degree-hours method (static) have been compared to estimate heating and cooling loads of building's wall. All main wall surfaces of various orientations, i.e.South, West, East, North, and horizontal are considered in the climate of Tehran, Iran. In this study, a conventional wall structure, which is comprisedconcrete as main wall material, and EPS (expanded polystyrene), as insulation material, areused. The actual outdoor air temperature (used in dynamic method) was obtained by mean hourly measurementsrecorded in meteorological data over the period of 2006–12. Annual heating and cooling degree-hoursare calculated based on this recent weather data, and results are compared with the values reported in the national building regulations (topic 14). One dimensional transient heat transfer problem for multilayer walls has been solved to obtain temperature distribution within the wall. Annual heating and cooling load resulting from dynamic method have been compared with degree-hoursmethod; the results showed that there is a significant difference between these two estimations.

Keywords: *dynamic transient method, heating and cooling degree-hours (HDH and CDH), heating and cooling load, national building regulations.*

1. Introduction

Increasing demand for energy in the recent years is a result of the population growth, urbanization, migration to larger cities, and improvement of living standards. Building sector (residential and commercial) is one of the most important parts of energy consumption in countries. Energy loss from the building envelope is one of the main sources of energy dissipation in buildings, since it serves as an interface between indoor and outdoor environments [1]. Implementation of insulations in walls is an important option to reduce the energy consumption in buildings. Finding proper material, design of building envelope,considering the location, and orientation of its components are an efficient means to reduce the annual heating and cooling load, and consequently the need for energy[2].

In Iran, the building sector share of energy consumption is nearly 37% of the total annual energy consumption [3]. Emission of carbon dioxide (CO_2), sulfur dioxide (SO_2) and other pollutant gases is the most important environmental issueregarding the energy

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consumption in buildings, especially in large cities. During the recent years, levels of pollutant gases in Tehran have increased hazardously, and become the cause of many diseases and fatalities; especially in winter, when the inversion worsens the situation. Based on reports of Ministry of Energy [3], the building sector (residential, commercial and public) share of emission of greenhouse gases is 25.6%.

An analysis of annual energy demand and cost, usually follows the design load demand calculations, and plays an important role in selection of heating, or cooling systems. The determination of heat gain/loss through walls, or roofs of a building is very important in selecting a suitable heating, or cooling systems that can efficiently use energy [4], [5]. There are various methods to calculate heating and cooling demand of a building. A simple and crude model to estimate heating and cooling load under static condition is known as degree-day, or degree-hours method, which is based on either ambient air temperature, or sol-air temperature. A ‘degree day’ or ‘degree-hours’ indicates that daily, or hourly mean outdoor temperature was 1°higher, or lower than some comfortable baseline temperature on a particular day, or hour. The sum of the number of heating, or cooling degree-days over a year is roughly proportional to the amount of energy that would be needed to heat, or cool a building in that location. The heating and cooling degree day assumes that energy demands for a building are proportional to the difference between the hourly mean outdoor temperature, and the base temperature. The base temperature is the outdoor temperature, above, or below which cooling, or heating is needed, respectively. Heating and cooling degree-hours are calculated at the base temperature of 18.3°C (65°F)[4]. It is acceptable to assume that this baseline temperature varies depending on the place specific characteristics of the building, non-temperature weather condition, including humidity, precipitation, wind, and cultural preferences. For example, a region with a housing stockcomprised of well-insulated homes will have a relatively low base point temperature. However, it is assumed that this base temperature throughout the world is the same, and equal to 18.3°C, which implicitly assumes that the temperature, where energy is demanded for heating and cooling service is the same everywhere[6].

A dynamic transient method can also be used to estimate a building's energy demand. In this method, the energy transferred through a building's wall depends on the wall's location and orientation, construction type, and weather parameter of the location.Dynamic transient method addresses some of the limitations of the degree-day method as the energy losses are calculated, based on the particular building's thermal properties, and to consider other weather parameters, such as, solar gains, wind etc.[7]. Dynamic building simulations are becoming commonly used to analyze performance of the envelope of new buildings, and performance of different passive and active heating, and cooling systems.

Considering the advance of passive and low energy buildings, it is necessary to applytransient methods, rather than simple, and crude method of degree day to achieve robustsolutions in building energy consumption. In Iran, building's regulations are mainly based on the simple method of degree-day[8].

The aims of this study are: (i) to investigate transient and degree-hoursmethods to estimate the energy loss/gain through the envelope of building in the climate of Tehran and comparethe results; (ii) to reevaluate energy demand based on the recent weather data,and compare with the data in the national buildings regulations.

2. Mathematical formulation

The number of annual HDH and CDH determined from following equation [9]:

$$HDH = (1year)\sum_{1}^{365}(1day)\sum_{1}^{24}(T_b - T_o)^{+} \qquad (1)$$

where, T_b is the base temperature and T_o is the outdoor temperature for each hour. The + sign above the parenthesis indicates that only positive values are to be counted, and the temperature difference is to be taken to zero, when $T_o > T_b$. The annual CDH can be defined in an analogous expression as:

$$CDH = (1year)\sum_{1}^{365}(1day)\sum_{1}^{24}(T_o - T_b)^{-} \qquad (2)$$

The - sign above the parenthesis indicates that only negative values are to be counted, and the temperature difference is to be taken to zero, when $T_o < T_b$.

Sol-air temperature, T_{sa}, is the outdoor temperature, including the effect of solar radiation on the outside of the opaque surface, such as, walls and roofs. This temperature is higher than the outside temperature. Sol-air temperature is defined by adding the effect of solar radiation as:

$$T_{sa} = T_o + \frac{\alpha_s I_T}{h_o} - \frac{\epsilon \Delta T}{h_o} \tag{3}$$

In the above equation, T_o, I_T, α and h_o are the outdoor air temperature, total solar radiation, solar absorptivity of the outdoor wall surface, and the outdoor surface combined convection and radiation heat transfer coefficient, respectively. The last term of equation (3), $\frac{\epsilon \Delta T}{h_o}$ is the correcting factor for the case of $T_{surr} \neq T_o$; ranging from 0˚C for vertical walls to 4˚C for horizontal walls facing to sky[4]. The combined heat transfer coefficient and solar absorptivity are taken equal to $22 w / m^2 K$, and 0.8, respectively[10]. In the equations 1 & 2 outdoor temperature can be substituted with sol-air temperature to address the energy loss/gain through the wall surface of various orientations.

Finally, annual heating and cooling demands using CDH method can be calculated asper the following equations:

$$\text{Heating energy Demand}\left(\frac{w.h}{m^2}\right) = HDH\,(K.h) \times \text{Overall heat loss coefficient}\left(\frac{w}{m^2 K}\right) \tag{4}$$

$$\text{Cooling energy Demand}\left(\frac{w.h}{m^2}\right) = CDH\,(K.h) \times \text{Overall heat loss coefficient}\left(\frac{w}{m^2 K}\right) \tag{5}$$

In the dynamic transient method, it is necessary to obtain the instantaneous temperature distribution throughout the wall. Hence, consider a common structure of an ordinary and convenient wall in Iran (Fig. 1).One dimensional heat transfer through the wall is to be considered. Therefore, in the Figure 1 boundary conditions, necessary thermo-physical properties, and thickness of the wall are presented. The outside layer of the wall is exposed to periodic ambient temperature, solar radiation; and the inside layerof the wall is exposed to convection resulting from constant air temperature inside the building.

Assuming no heat generation, constant thermal properties, one-dimensional conduction heat transfer, and negligible interface resistance, unsteady heat conduction equation for each layer of a multi-layer wall is as follows [11]:

$$\frac{\partial^2 T_j}{\partial x_j^2} = \frac{1}{\alpha_j}\frac{\partial T_j}{\partial t} \tag{6}$$

where $\alpha_j = k_j / \rho_j c_j$ is the thermal diffusivity of each layer, k_j, c_j, and ρ_j are the thermal conductivity, the heat capacity, and the density of each layer, respectively. Two boundary conditions on both sides of the multi-layer wall and one initial condition are needed to solve the problem. Constant inside temperature at t=0 is considered initially [12]. On the both sides of the wall, convection heat transfer exists. On the inside of the wall, convection boundary condition is as follows:

$$-k_G \left.\frac{\partial T}{\partial x}\right|_{x=L} = h_i \left(T_{x=L} - T_i\right) \tag{7}$$

In the above equation, h_i is the inside combined (convection and radiation) heat transfer coefficient, and T_i is the indoor temperature, which is taken to be constant. At the outer surface of the wall, the boundary condition can be written as given below:

$$k_C \left.\frac{\partial T}{\partial x}\right|_{x=0} = h_o \left(T_{x=0} - T_{sa}(t)\right) \tag{8}$$

Total solar radiation on the wall surface with various orientations is assessed by the method presented by Duffie and Beckman [13]. Based on this method, the relationship between solar time and standard time is given below:

$$\text{solar time} = \text{standard time} - 4\left(L_{st} - L_{loc}\right) + E \tag{9}$$

where L_{st} the standard meridian for local time zone is, L_{loc} is the longitude of the location, and E is the equation of time, which is expressed as below:

$$E = 229.2\big(0.000075 + 0.001868 CosB - 0.032077 sinB - 0.014615 cos 2B - 0.04089 \sin 2B\big)\cdots \tag{10}$$

In the above equation B (in degrees) is defined as follows:

$$B = (n-1)\frac{360}{365} \qquad 1 \le n \le 365 \qquad (11)$$

where n is the day of the year.

The geometric relationship between a plan of any particular orientation relative to the earth at any time, and any incoming beam solar radiation can be described in terms of several angles [13].

The angular position of the sun at solar noon regarding the plan of equator is declination angle, δ and varies $(-23.45° \le \delta \le 23.45°)$ throughout the year, and can be calculated by the following equation:

$$\delta = 23.45 \sin\left(360 \frac{284+n}{365}\right) \qquad (12)$$

$$n = the\ day\ of\ the\ year \quad 1 \le n \le 365$$

There is a set of useful relationships between the angles. The angle of incidence (θ) between the sun's rays, and a tilted surface is given by:

$$\begin{aligned}\delta \cos(\theta) = {} & \sin(\delta)\sin(\phi)\cos(\beta) \\ & - \sin(\delta)\cos(\phi)\sin(\beta)\cos(\gamma) \\ & + \cos(\delta)\cos(\phi)\cos(\beta)\cos(\omega) \\ & + \cos(\delta)\sin(\phi)\sin(\beta)\cos(\gamma)\cos(\omega) \\ & + \cos(\delta)\sin(\beta)\sin(\gamma)\sin(\omega)\end{aligned} \qquad (13)$$

where δ, ϕ, ω and γ are declination angle, latitude angle, hour angle, and surface azimuth angle, respectively. β Is is the slope of the surface ranging from 0 for horizontal surface, and 180 for horizontally upside down surface.It is notable that $\beta=0$ represents the vertical wall. Surface azimuth angle varies between $-180 \le \gamma \le 180$ $(\gamma = -180, -90,\ 0, 90\ and\ 180$ are for the surface faced to North, East, South, West and again North, respectively). Hour angle, which is the angular displacement of the sun East, or West of the local meridian, due to rotation of the earth on its axis at $15°$ per hour; being negative in the morning, and positive in the afternoon, is calculated in minute by the following equation:

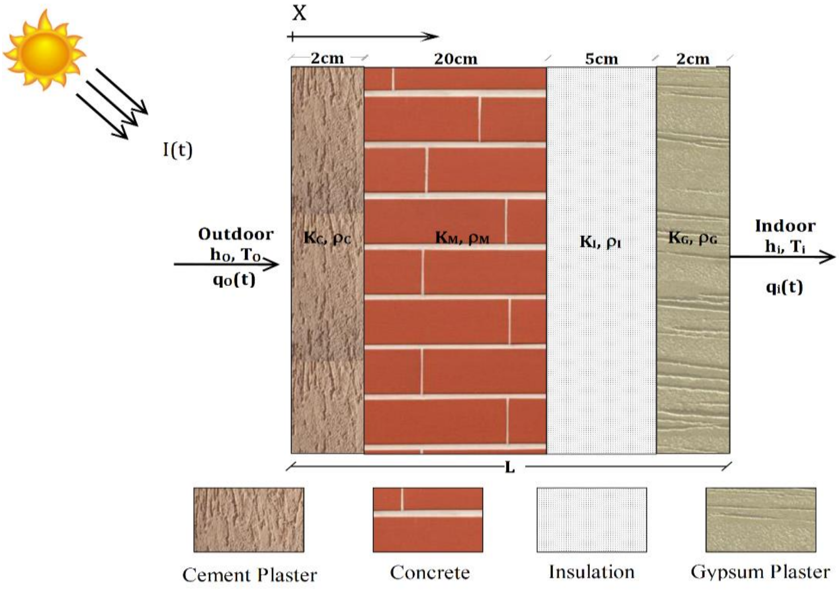

Fig. 1. A schematic of an ordinary multi-layer wall in Iran

$$\omega = \frac{360}{24}\frac{(Solar\,Time - 720)}{60} \qquad (14)$$

The angles between the vertical and the line to the sun are the zenith angle (θ_z), which has the following relationship:

$$\cos(\theta_z) = \sin(\delta)\sin(\phi) + \cos(\delta)\cos(\phi)\cos(\omega) \qquad (15)$$

Setting the cosine of the angle to zero in the equation (12) results in the relation for the hour angle (ω_s) at the sunset:

$$\cos(\omega_s) = -\tan(\phi) tan(\delta) \quad (16)$$

The sunrise hour angle is the negative of the sunset hour angle. It follows that the number of daylight hour is given by:

$$N = \frac{2}{15}\cos^{-1}\left(-\tan(\phi)\tan(\delta)\right) \quad (17)$$

It takes 60 minutes to transverse 15° of longitude, the exact time of sunset (in minutes) can be found by:

$$sunset\ time = \frac{60}{15}\cos^{-1}\left(-\tan(\phi)\tan(\delta)\right) \quad (18)$$

and sunrise time can be calculated using equations (17) and (18):

$$sunrise\ time = sunset\ time - N \quad (19)$$

The geometric relationship between a plan of any orientation on the earth, and incoming beam solar radiation is revealed, when the above mentioned angles are determined, and one can use an isotropic clear sky method of Hottle [14]. The details of the method of calculation can be found in Duffie and Beckman [13]. Here, introduce the equation for calculation of total solar radiation, which is used in the sol-air temperature in equation 3, as follows:

$$I_T = R_b I_b + I_d\left(\frac{1+\cos(\beta)}{2}\right) + I\rho_g\left(\frac{1-\cos(\beta)}{2}\right. \quad (20)$$

where I_b, I_d, and I are beam, diffuse, and total solar radiation on the horizontal surface (three main components of radiation on a tilted surface). In equation (20) ρ_g is the ground reflectance and usually taken as 0.2 and R_b is a geometric factor which can be calculated by:

$$R_b = \frac{\cos(\theta)}{cos(\theta_z)} \quad (21)$$

3. Numerical Procedure

One dimensional transient heat conduction problem within a multilayer wall, under the dynamic boundary condition on outside surface is considered. The transient heat conduction problem has been numerically solved, by using an implicit finite difference procedure for multilayer wall. General finite difference equations, derived by Ozel and Pihtili [15], are used to obtain the set of equations. Gauss-Seidel Iterative method was used to solve linear system of equations with inner wall temperature as the initial approximation [16]. A MATLAB code was developed to accelerate the numerical computation. Inputs of the code include thermo-physical, and geometrical properties of each layer of the wall and time dependent sol-air temperature, while the output is the propagated temperature wave on the inside surface of the wall. Boundary condition was assumed to be periodic at the outside; therefore, until reaching the steady solution, the daily cycle of solution of equations with sol-air temperature at the outside was repeated. The combined heat transfer coefficient in the inside of the envelope, h_i and combined heat transfer coefficient at the outside were taken equal to $8\ \mathrm{w/m^2K}$ and $22\ \mathrm{w/m^2K}$, respectively[10].

On the 21st of each month is considered as the representative day for calculation of both cooling and heating demands [10]. As mentioned before, temperature of indoor is assumed to be constant throughout the day, and hence instantaneous heat transfer through a wall, after determining the inside wall temperature $T_{x=L}$ from numerical solution, can be calculated as follows:

$$q_i = h_i\left(T_{x=L} - T_i\right) \quad (22)$$

Integrating this value over the day, daily heating, or cooling transmission load can be obtained. Annual heating and cooling transmission loads are also obtained by daily heating, or cooling load over its season. A flowchart for the numerical procedure is shown in Fig. .

Constant inside temperature is selected, based on thermal comfort, and energy saving for each month [11], is used in thiscalculation, and shown in Table 1 for each month of the year.

Conventional walls and roofs in Tehran have been considered in this study. The walls and roofs consist of 2cm cement plaster at the outer layer, 2cm gypsum in the inner surface, and 20 cm main wall material, usually concrete. Insulation layer is placed inside surface of the main wall materialused to save energy. The most conventional insulation material, EPS is used. Thermo-physical properties of material used in this study have been shown in Table 2.

The degree-hours method T_b is constant throughout a year. However, in this study annual energy demand is calculated, based on both the constant temperature of 18.3°C (65°F), and the constant inside temperature is shown in Table 1. The first one is compared with the values in the national buildings regulations data, and the other with the current dynamic method.

4. Results and Discussions

This study focuses on calculation of heating and cooling load ofa common wall structure located in Tehran, Capital of Iran (which has the geographical coordinate of 35°41'39" N and 51°25'17" E). All walls surface of various orientations (South, West, East and North) and horizontal wall were investigated. The actual outdoor air temperature was obtained by the meanrecorded meteorological date, over the period of 2006–12[17]. The data pertain to a representative day of each month during a year. Two-hourly outdoor air temperatures resulting from the mean over the aforementioned period, for July 21 and January 21, represented summer, and winter season respectively, are shown in Figure 3.

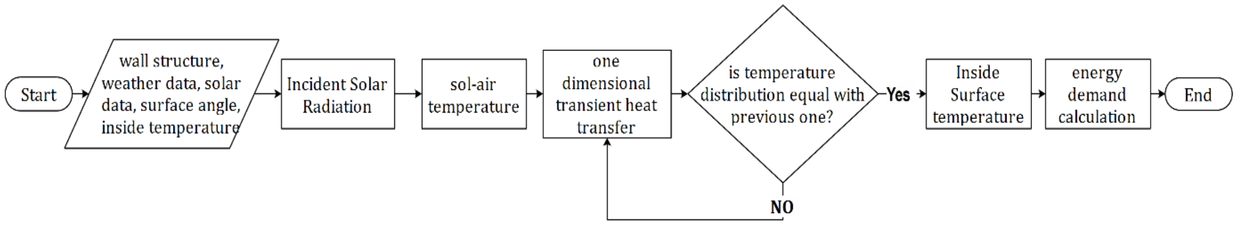

Fig. 2. Flow Chart of numerical simulation for transient method

Table 1. Constant indoor temperature in each month

Month	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Temperature(°C)	20	20	20	22	23	23	23	23	23	22	20	20

Table 2. Thermo-physical properties of the materials used in the paper

Materials	Thermal Conductivity $k(\frac{W}{m.K})$	Density $\rho\left(\frac{Kg}{m^3}\right)$	Specific Heat $C\left(\frac{J}{Kg.K}\right)$
concrete block	1.37	2076	880
cement plaster	0.7	2778	840
gypsum plaster	0.18	800	1090
Expanded Polystyrene(EPS)	0.038	17	1500

The clear sky model has been used to take the solar radiation on the wall surface into account. For the representative day of each month during the year, solar radiation has been calculated for wall surface of various orientations.

Figure 4 shows hourly incident solar radiation on the wall surface of various orientations in two representative days of the summer and winter; 21st July, and 21st January. Incident solar radiation on the surface begins with sunrise, and finishes as the sun sets. Different wall orientations receive different solar radiations in both magnitude, and the time of day. Therefore, the maximum values of the incident radiation take place at different times for each orientation. East and West-facing walls received the same magnitude, but symmetrically around noon. It is seen from this figure that unlike the July, the highest value of solar radiation for wall surface of various orientations belongs to South-oriented wall during January. It is also notable that solar radiation on the North-facing wall in July has two maximum values at two different times during the day.

Sol-air temperature is obtained by using Equation (3). Sol-air temperature, which is a combination of radiation and ambient air temperature, is shown in Figure 6 for the representative days of January and July. Sol-air temperature is the actual temperature on the outside of the wall, and it is changed by the incident solar radiation received on each orientation. These instantaneous temperatures on outside the wall penetrate through the wall during the day. Therefore, its amplitude and time at temperature is maximum or minimum, changed depend on the structure of the wall.

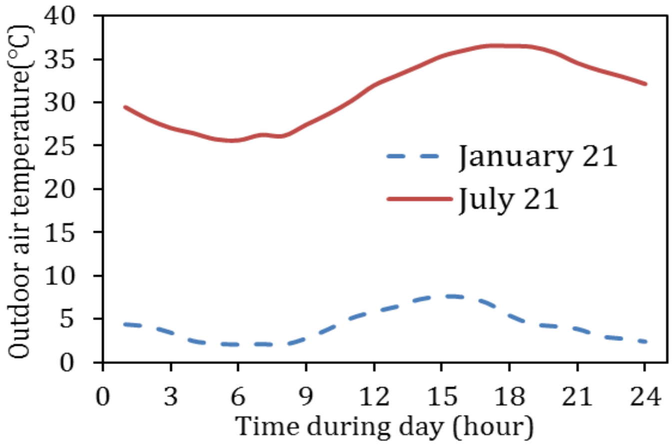

Fig. 2. Meanoutdoor air temperature in representative days of summer and winter

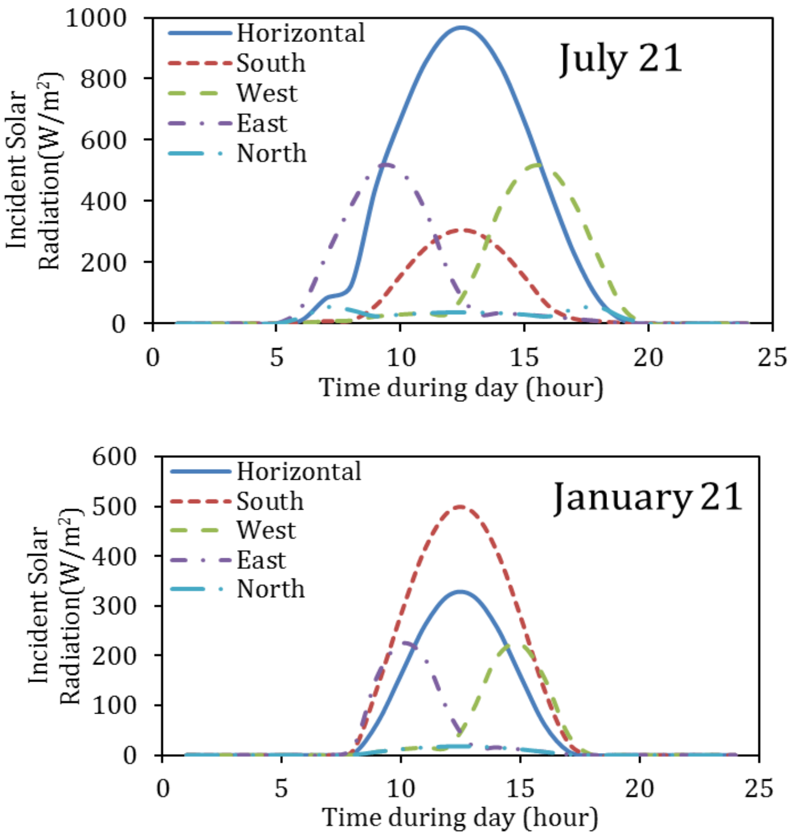

Fig. 3. Hourly incident solar radiation on surface of various orientations in representative days of July(summer), and January(winter)

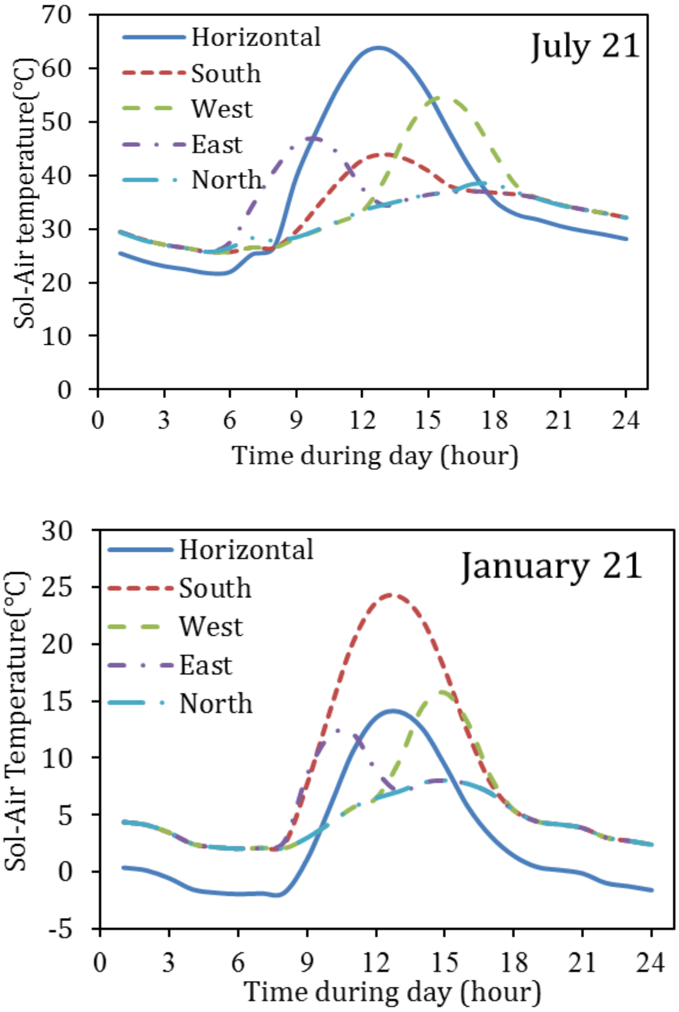

Fig. 4. Sol-air temperature of wall surface of various orientationsin representative days of July(summer), and January(winter)

Wall temperatures in the inside surface, resulting from numerical solution, for July and January are shown inFig. 5. This temperature in the inside of the wall is used to calculate the energy demand through the wall in dynamic method. Inside wall temperature depends on the incident solar radiation. There is a lag between the time when sol-air temperature, and inside temperature are maximum, or minimum. This time lag depends on the wall's structure.

Theannual heating and cooling demands are calculated using the degree-hours method. At this stage, the base temperature is set to be equal to 18.3°C. Energy demand in terms of annual heating or cooling hours is obtained based on both outdoor and sol-air temperatures. The results are presented in Tables 3–4, for heating and cooling degree-hours, respectively. In these tables, HDH and CDH from the national buildings regulations (part 14) are also tabulated for comparison. The calculation is based on outdoor temperature. There is no distinction between wall's orientations, while energy demand for sol-air temperature varies with wall's orientation drastically. There are considerable differences, especially for CDH, between current calculation, and national building regulations data, which can be explained by the weather data used in each calculation. There must be careful cautious in application of HDH and CDH of the national building regulations in estimation of energy demand, despite they are useful in the rules of thumb to estimateannual energy demand.

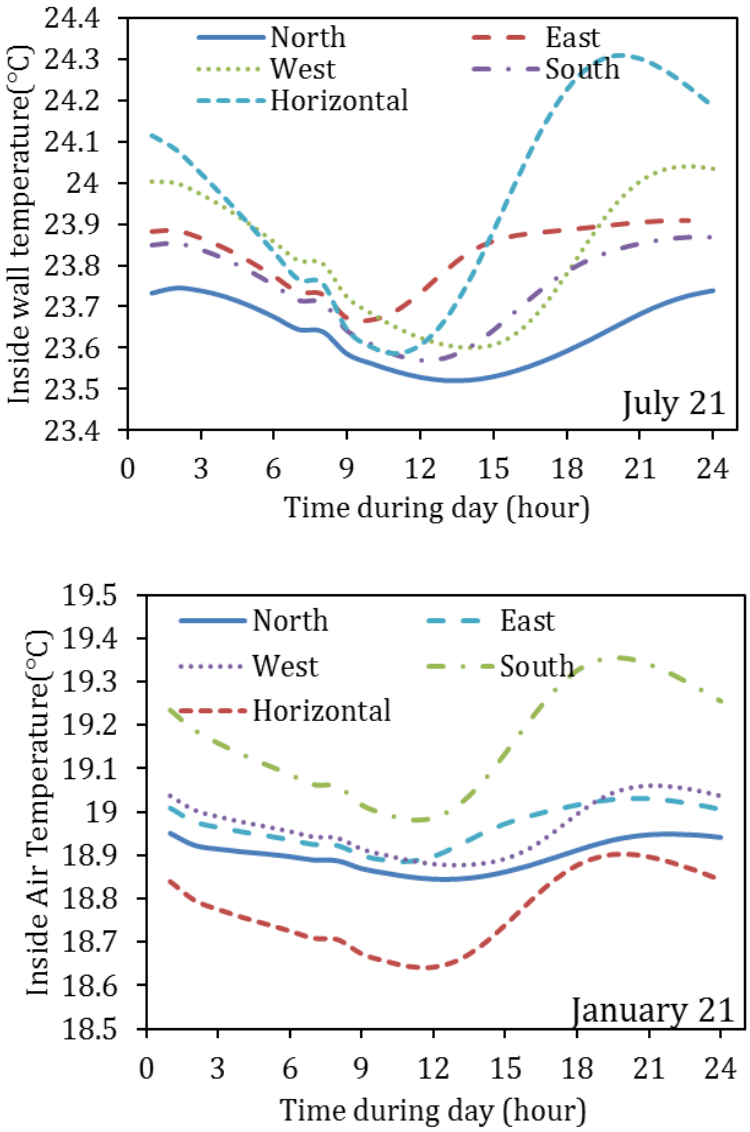

Fig. 5. Inside wall surface temperature of various orientations in representative days of July(summer) and January(winter)

Constant inside temperature is applied to calculateannualenergy demand with both transient and degree-hours method (Table 1). Annual heating and cooling demand per square meter of the wall's surface, which is obtained by both the dynamictransient, and degree-hours (based on both outdoor temperature, and sol-air temperature) methods, are presented in Figure 6 and 7, respectively. Transient method has a tendency tounder-estimate heating and over-estimate cooling demands compared to the degree-hours method, based on outdoor temperature. The same trend is observed in the energy demand calculated by degree-hours method, based on the sol-air temperature. However, this method predicts demand higher than transient method. This deviation can be explained by the nature of the method, and also assumptions of clear sky model. Transient method specifies the energy demand instantaneously. Therefore, it is necessary to use this method in passive buildings. The mean energy demand /m^2 of various orientations is presented in Table 5 for different methods. It is seen that degree-hours methods bead on outdoor temperature predicts higher heating demand, and lower cooling demand than the two others methods.

Table 3. HDH based on outdoor and sol-air temperature, and HDH from the national building regulations (part 14) (Tb=18.3)

Wall's orientation	HDH based on outdoor temperature(Tb=18.3)	HDH based on sol-air temperature(Tb=18.3)	HDH from National building regulations
South	1723	1269	1810
Horizontal	1723	1996	1810
West	1723	1501	1810
East	1723	1445	1810
North	1723	1626	1810

Table 4. CDH based on outdoor and sol-air temperature, and CDH from the national building regulations(topic 14) (Tb=18.3)

Wall's orientation	CDH based on outdoor temperature(Tb=18.3)	CDH based on sol-air temperature(Tb=18.3)	CDH from National building regulations
South	1514	1564	865
Horizontal	1514	1885	865
West	1514	1609	865
East	1514	1574	865
North	1514	1205	865

The cloudiness and anisotropic radiation, especially in winter, can affect the results of transient method. However, dynamic transient simulations are becoming commonly used to analyze the performance of the envelope of new buildings. TAS, BSim, IES, IDAICE, and Energy Plus are the examples of simulation programs that apply transient method in their calculations. To verify the accuracy of each method, experimental measurement is required. However, it is recommended that degree-hours method may be used carefully in real engineering design.

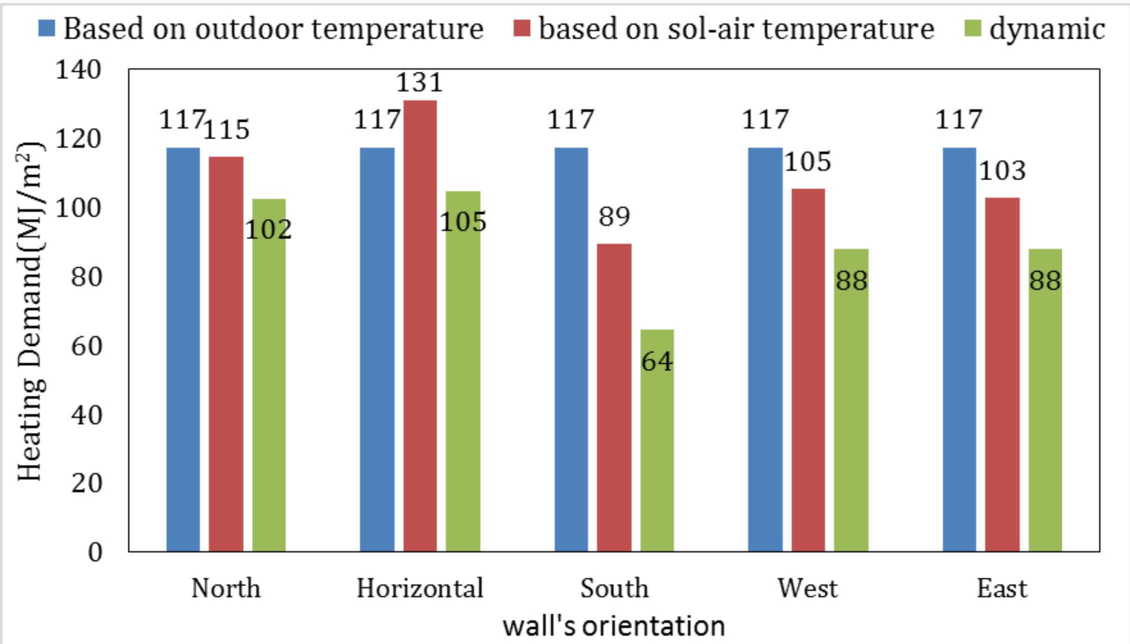

Fig. 6. Annual heating demands for all walls orientation obtained with both degree-hours method (based on both sol-air temperature and outdoor temperature) and dynamic transient method

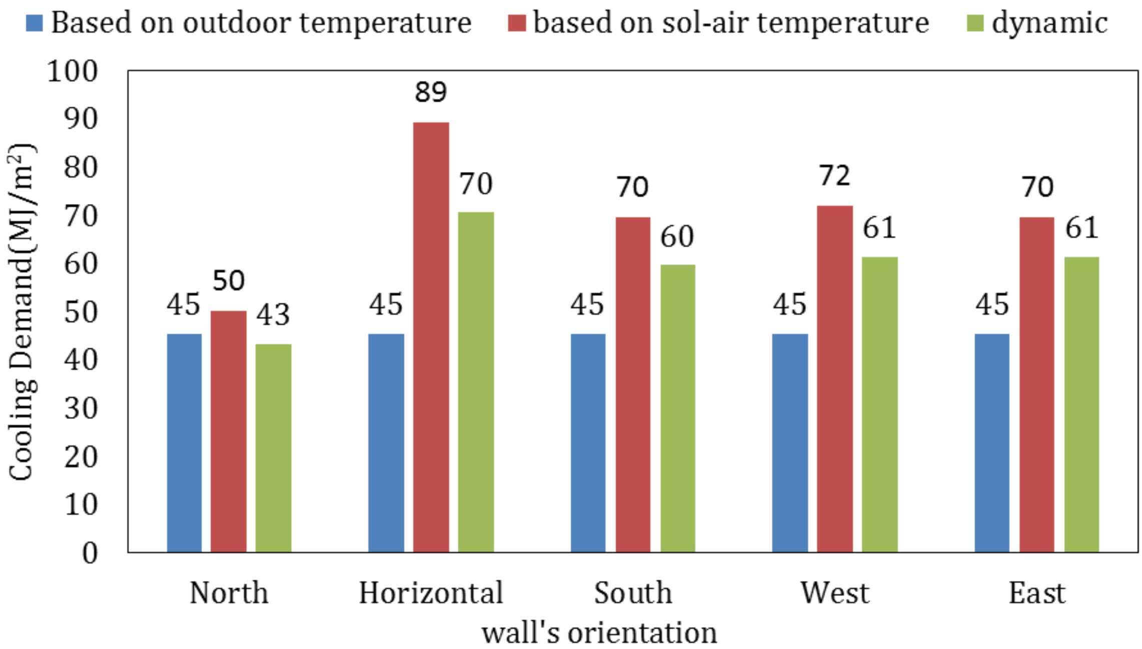

Fig. 7. Annual cooling demands for all walls orientation obtained with both degree-hours method (based on both sol-air temperature, and outdoor temperature), and dynamic transient method

Table 5. Meanannual energy demand over surface of various orientations calculated with different methods

calculation method	Demand(Mj/m^2)
average cooling demand(CDH method based on outdoor temperature)	45
average cooling demand(CDH method based on sol-air temperature)	70
average cooling demand(dynamic method)	59
average heating demand(HDH method based on outdoor temperature)	117
average heating demand(HDH method based on sol-air temperature)	109
average heating demand(dynamic method)	89

5. Conclusion

The two methods of estimation of heating, and cooling demand for wall of various orientations are compared together. The first method is degree-hours, which is a crude and simple method, while the other method is a dynamic transient method. Data in the national buildings regulations are also examined with the recent weather data. The results showed that the data should be reevaluated in real calculations. It is shown that transient method over-estimates cooling load, and under-estimates heating load compared to the degree-hours method. Due to the wide-spread application of transient method in energy simulation software, experimental measurement is required to validate the results.

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Nomenclature

Alphabetic symbols

B	dummy variable, (n-1) 360/365
c	heat capacity($\frac{J}{Kg.K}$)
E	equation of time
h_i	indoor surface combined convection heat transfer coefficient($\frac{J}{m^2.K}$)
h_o	outdoor surface combined convection heat transfer coefficient($\frac{J}{m^2.K}$)
I	total solar radiation on horizontal surface($\frac{W}{m^2}$)
I_b	beam solar radiation on horizontal surface ($\frac{W}{m^2}$)
I_d	diffuse solar radiation on a horizontal surface($\frac{W}{m^2}$)
I_T	total solar radiation($\frac{W}{m^2}$)
k	thermal conductivity($\frac{W}{m.k}$)
L_{loc}	longitude of the location
L_{st}	standard meridian
t	time (s)
n	the day of year
N	number of daylight hours
q	heat transfer($\frac{W}{m^2}$)
R_b	geometric factor
T_b	base temperature(K)
T_o	outdoor air temperature(K)
T_{sa}	sol-air temperature(K)
T_{surr}	surrounding temperature(K)
x	distance(m)

Greek Symbols

α	thermal diffusivity($\frac{m^2}{s}$)
α_s	solar absorptivity
β	slope of the surface
γ	surface azimuth angle
δ	declination angle
ΔT	temperature difference(K)
θ	angle of incidence
θ_z	zenith angle
ρ	density($\frac{K}{m^3}$)
ρ_g	ground reflectance
ϕ	latitude angle
ω	hour angle

Acronyms

EPS	expandedpolystyrene
ADH	annual degree hours
HDH	heating degree hours
CDH	cooling degree hours