A FULL 3^4 FACTORIAL EXPERIMENTAL DESIGN FOR THE LOW ENERGY BUILDING'S EXTERNAL WALL

by

Tugce PEKDOGAN[a*], Sedat AKKURT[b], and Tahsin BASARAN[a]

[a] Izmir Institute of Technology, Department of Architecture, Izmir, Turkey
[b] Izmir Institute of Technology, Department of Mechanical Engineering, Izmir, Turkey

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The low energy building concept is based on improving the building envelope to reduce heating and cooling loads. Improvements in building envelopes depend not only on climatic conditions but also on insulation. In this study, the thermal performance of external walls was studied by using a three-level full factorial statistical experimental design. An opaque wall in low energy buildings was chosen in order to study the effect of selected factors of city (A), orientation (B), insulation location (C), and month of the year (D) on heat loss or gain. A software was used to calculate the ANOVA table. As a result, all three factors of months of the year, city and orientation of the building façade were found to be significant factor effects for heat transfer. Two-factor interactions of AB, AD, BD, and CD were found to be significant. Therefore, the effects of season, location and orientation were successfully shown to be effective parameters.

Key words: *thermal insulation, factorial experiment, statistical analysis, design of experiment method, low energy building*

Introduction

Because a significant proportion of total energy consumption occurs in buildings, understanding the transfer of heat through the building envelope has become even more important. Thermal insulation is applied to reduce the costs of heating and cooling energy, which is limited from inside to outside or outside to inside, depending on the severity of external climatic conditions, in order to provide thermal comfort conditions in the indoor environment. Thermal insulation materials should be used in such combinations as to take into account the external factors (wind, temperature, relative humidity, and radiation) as well as the design of the building elements to obtain improved thermal performance.

The annual heating and cooling loads are taken into consideration when determining the insulation thickness. Many authors have investigated the optimum insulation thickness in different climate regions. As some of these studies [1-6] have been developed under steady-state, thermal inertia effects of building' external walls are not taken into account. It is known that thermal inertia has a significant effect on time-dependent heat transfer from the external walls [7-17]. Arslanoglu and Yigit [1] calculated optimum insulation thickness for different regions of Turkey namely, Ankara, Erzurum, Istanbul, Izmir in order to use 1-D steady-state heat transfer model. Furthermore, each of the four parameters (wall, insulation and fuel types, heating degree day – HDD) was analyzed with ANOVA and Taguchi method. Sevindir *et al.* [2]

[*] Corresponding author, e-mail: tugcepekdogan@iyte.edu.tr

suggested a new analytical method to determine optimum insulation material under steady-state conditions by using degree-days method. Kurekci [3] calculated optimum insulation thicknesses of different cities of Turkey for multilayer external walls by using degree-day method which is commonly used for calculating the energy consumption of the building. He also investigated the pay-back periods with natural gas, coal, fuel-oil, and LPG, respectively. Jraida *et al.* [4] determined optimum insulation thicknesses for different zones of climate in Morocco based on the life-cycle cost analysis with degree-days method. Kayfeci *et al.* [5] compared optimum insulation thickness of multilayer exterior walls based on degree-hours and annual equivalent full load cooling-hours operation methods. Ucar [6] investigated the optimum insulation thickness considering water vapor condensation through the external walls of various cities from Turkey, namely, Antalya, Istanbul, Elazig, and Erzurum by using exergoeconomic analysis

On the other hand, time-dependent heat transfer problem considers sensible energy storage of building' external walls. Pekdogan and Basaran [7] studied the thermal inertia effect by solving a 1-D time-dependent heat transfer problem for different parameters. The thermal performance of various external wall structures based on wall orientation, wall thickness and insulation location based on different climate zones in Turkey were numerically analyzed in terms of time-dependent thermal behaviors. Fathipour and Hadidi [8] investigated time lag and decrement factor for different building materials for exterior walls solved analytically using Green function under time-dependent convection boundary conditions in Iran. Nematchoua *et al.* [9] optimized the thermal insulation thickness in equatorial and tropical climate regions based on energy usage and pay-back period analysis with the numerical solution of transient heat transfer through multilayer walls related to the average outdoor temperature, solar radiation, and shading effect. Ferroukhi *et al.* [10] established a coupled heat, air, and moisture transfer model in multilayer walls. Wati *et al.* [11] calculated the optimum exterior wall insulation thickness by using finite difference method. Energy savings and the pay-back period were investigated as a function of orientation and incorporating the shading effect. Dedinec *et al.* [12] solved the transient heat transfer model and analyzed the energy saving potential in the construction of a new and existing buildings with different heating systems related to a cost-effective energy saving optimization. Ozel [13] determined the effect of insulation location and thickness with an implicit finite difference method under periodic conditions. The results showed that the insulation location has an important effect on the time lag and decrement factor. Ibrahim *et al.* [14] identified various combinations and locations of insulation layer which is silica-aerogel on the external walls and examined the heating and cooling loads of the buildings. Another experimental study was carried out verification of a model about 1-D transient heat conduction problem by Merabtine *et al.* [15]. Gagliano *et al.* [16] investigated the effect of thermal inertia with natural ventilation on a historic building wall. Numerical and experimental results have shown the high potential of ventilation and thermal mass combination prevent overheating during summer, as noted in Basaran's study [17]. Andjelković *et al.* [18] investigated the thermal mass effect of a building and they compared lightweight with heavy mass structures by using a dynamic thermal simulationol. Axaopoulos *et al.* [19] examined optimum insulation thickness for multi-layered exterior walls with different climatic conditions in Greece and addressed the building's wind direction, speed, and orientation with respect to different wall configurations. Sun *et al.* [20] investigated the influence of time-lag of the minimum and maximum temperature peak and decrement factor between internal and external temperatures experimentally and numerically for different building envelope schemes.

The calculation of heating and cooling load for external wall of a building must meet some requirements related to the environmental impact, such as wind, temperature, relative humidity and radiation, type of building material as well as inside air quality. A parametric study using simulationols can help designers choose the most appropriate solution according to the location of the city, orientation, insulation location and months of the year. However, performing such a parametric operation is quite complex and time-consuming, hence requires a large number of simulation runs. There are many factors that need to be taken into consideration in order to calculate the heating and cooling load on the building exterior walls, such as building heat insulation, building orientation, building occupancy, building thermal inertia, and so on. Moreover, these factors may interact with each other, making it difficult to make straightforward inferences. Statistical experimental design techniques help minimize the number of experimental runs by carefully balancing the experimental conditions and eliminates the necessity to run a large number of treatments to draw statistically valid conclusions. The result is significant savings of resources. Alizadeh and Sadrameli [21], for example, employed central composite design to develop a model for thermal comfort in buildings. In another study, Jung *et al.* [22] used a full factorial design to study the energy storage time of the PCM, and Celik *et al.* [23] studied the effect of different parameters on pressure drop of fluid across perforated plates via the use of designed experiments, while Ramkumar and Ragupathy [24] investigated cooling tower performance using Taguchi method. Examples are plentiful in the literature. The latest reviews in the literature about data processing for the prediction of building energy consumption studies are published by Wei *et al.* [25] and Amasyali and El-Gohary [26].

A research project aimed at understanding the effects of input parameters like location of city, orientation, insulation location and months of the year, on heat loss/gain through the wall will require prohibitively large number of experiments if the classical one factor at a time approach is utilized because it involves each factor to be studied at several different levels (*e. g.* Orientation 0-360° studied at every 5° intervals) while all other factors are kept constant. This type of experimental planning rapidly inflates the number of tests to be done. However, when designed experiments are utilized, research resources are used more efficiently [27]. This study shows an example of how designed experiments can be employed to accelerate a research program with minimal experimentation and time [28]. With a factorial design, analysis can be performed in a balanced way with the least possible number of experiments to observe the differences in heat transfer capacities.

The purpose of this study is to identify the effects of the aforementioned factors on heat transfer through an opaque wall using statistical experimental design methodology. Another potential outcome of the study is to develop a model which may predict the effects of factors on the response. The model is actually a link between the independent variables (input) and the response (output) to them. First, the mathematical procedure used for calculation of the heating/cooling load of the building is explained, next to some information about designed experiments is given, and finally, the developed model is discussed. Data are processed by calculating the heat loss/gain through the wall which constituted the output (response) variable. The input factors are planned using statistical experimental design tools as discussed in the following sections.

Mathematical method

As the heat gain/loss from an opaque wall surface constitutes the output/response variable of the study, its measurement is explained below. Solar radiation on the outside surface, weather conditions, and the convective heat transfer coefficient are defined by time-dependent variables. On the inner surface of the wall, the convective heat transfer coefficient was kept at a constant value and the heat transfer from the wall exposed to the room temperature are considered. Therefore, a 1-D heat conduction equation in a parallel, isotropic and homogeneous multilayered wall is written for time-dependent and non-heat-producing conditions:

$$k\frac{\partial^2 T(t,x)}{\partial x^2} = \rho c_p \frac{\partial T(t,x)}{\partial t} \tag{1}$$

In this equation k, ρ, and c_p represent the heat transfer coefficient, density and specific heat of the structural elements, respectively. Accordingly, boundary conditions and initial condition for this multi-layered wall structure are defined:

$$-k_0\frac{\partial T}{\partial x}1_{x=0} = \alpha I + \sigma\varepsilon\left(T_{sky}^4 - T_{s,0}^4\right) + h_o\left(T_{\infty,o} - T_{s,0}\right),\ t>0,\ x=0 \tag{2}$$

$$-k_L\frac{\partial T}{\partial x}1_{x=L} = h_i\left(T_{s,L} - T_{\infty,i}\right), \quad t>0,\ x=L \tag{3}$$

$$T(x,0) = T_{\text{initial}}, \quad 0 \le x \le L,\ t=0 \tag{4}$$

In addition, the intersection points of each wall component are defined as in eq. (5):

$$x:\text{at interface boundary},\ t>0 \Rightarrow \left(-k\frac{\partial T}{\partial x}\right)_{\text{Layer 1}} = \left(-k\frac{\partial T}{\partial x}\right)_{\text{Layer 2}} \tag{5}$$

In the previous equations, k_0 and k_L represent the thermal conductivity of the plaster material on the outside and inside surfaces. The α and I represent the solar absorptivity defined as 0.4 and the total solar radiation intensity for a vertical surface for Erzurum, Ankara and Izmir, respectively [29]. The σ-value is $5.67\cdot10^{-8}$ W/m^{2}K^4, Stefan-Boltzmann constant for describing radiation from the surface. The ε represents the emissivity of the outside surface and is assumed to be 0.93 [30].

The $T_{s,0}$ and $T_{s,L}$ gave here are the internal and external surface temperatures, respectively. The $T_{\infty,i}$ is the inside temperature and is assumed to be constant at 22 °C for selected months. On the other hand, $T_{\infty,o}$ reflects the change of the outside air temperature during the day determined by the monthly average data. The atmospheric effective sky temperature T_{sky} [K] is expressed as in eq. (6) [30]:

$$T_{\text{sky}} = T_{\infty,o}\left(0.8 + \frac{T_{dp}}{250}\right)^{0.25} \tag{6}$$

where the sky temperature, T_{sky}, varies with climatic conditions depending on time and is defined using the dew point temperature T_{dp}, and the outside air temperature $T_{\infty,o}$ according to different cities. The dew point in the Kelvin unit is associated with relative humidity and air temperature. The h_i and h_o parameters represent the convective heat transfer coefficients on the inside and outside surfaces of the wall, respectively. The internal surface convective heat transfer coefficient is taken as 1/0.13 W/m^{2}K as defined in TS825 [31]. On the other hand, the outside surface convective heat transfer coefficient is defined as in eq. (7) depending on the wind speed, V_s, in m/s [32]:

$$h_o = 6.31V_s + 3.32 \tag{7}$$

where the constants 6.31 and 3.32 in eq. (7) were defined in the units individually confirmed the unit of the convective heat transfer coefficient [32]. The T_{initial} is the initial temperature for the defined wall section and is made the primary variable to the meshed (models of network structure) areas. The result is taken as the new starting temperature distribution for the next iteration. In this study, iterations are repeated until the highest difference between the results of two succeeding iterations becomes 0.01% for the temperature value along the wall section. Therefore, the temperature values through the wall are obtained by using the calculated final loop results and eventually heat transfer rates are quantified.

Interactive maps in photo-voltaic geographic information systems (GIS) are used to calculate time-dependent solar radiation values [29]. These interactive maps are developed using software defined by the solar radiation model in the European subcontinent into the GIS software called GRASS [33]. Solar radiation algorithms are based on the equations published in the European Solar Radiation Atlas [34]. The locations of the selected cities in this study, the climatic conditions, in addition these Trewartha and Thornthwaite climate classification systems are given in tab. 1 [35]. In addition, other climatic data such as: temperature, relative humidity, wind, and HDD, cooling degree days (CDD) for the province of Erzurum, Ankara, and Izmir are obtained from The Ministry of Forestry and Water Affairs and General Directorate of Meteorology [36]. The HDD and CDD values are indicators of the intensity of the need for heating and cooling in buildings. The HDD, for example, is calculated monthly or annually by summing up daily differences between reference inside temperature and outside average temperature. Hence, the higher their values, the higher are the energy consumption. The HDD and CDD are not used in this study in calculations but is only introduced here to help better classify the climatic differences in the selected cities. In this case, according to tab. 1, Izmir has a Mediterranean climate in the hot summer, while it is cool and rainy in the winter. For Izmir, monthly average temperatures are 6.8 °C for January, 15.8 °C for April, and 28.4 °C for July. In Ankara, the predominant climate features are hot and dry summers and cold winters with low precipitation. As far as the city of Ankara is concerned, monthly average temperatures are –1.1 °C for January, 10.5 °C for April, and 23.6 °C for July. Finally, the city of Erzurum, which is located 1757 m above sea level, is well known for its harsh winters along with mild and dry summers. Monthly average temperatures in this city are –12.3 °C for January, 5.3 °C for Apryl, and 18.8 °C for July [35]. As can be seen in tab. 1, selection of the cities is based on HDD and CDD values as well as the differences in climate classification systems.

Table 1. Climatic conditions of selected cities in different climate regions of Turkey [35, 36]

City	Latitude	Longitude	Trewartha	Thornthwaite	HDD	CDD
Erzurum	39° 95 N	41°17 E	Cold winters mild summers	C1 Semi-arid, low humidity C2 microthermal	4425	16
Ankara	39° 95 N	32° 88 E	Cold winters hot summers	D Semi-arid B1 mesothermal	2393	251
Izmir	38° 43 N	27°17 E	Cool winters hot summers	C1 Semi-arid, low humidity B3 mesothermal	985	660

The structure of the composite walls

Heat transfer through external wall surfaces of buildings is highly important for reducing heat transfer rate and for providing thermal comfort for different climatic conditions and orientations. In this report, an insulated opaque wall which is widely used in the sector is parametrically analyzed regarding their time-dependent thermal behaviors. As shown in fig. 1, the actual construction of the insulated concrete wall has the following layers; cement plastering, 15 cm XPS (extruded polystyrene foam), 20 cm concrete as a body element and gypsum plastering. Thermophysical properties of each layer are given in tab. 2 which are defined in TS825 and ASHRAE [31, 37]. In addition, inside and outside plaster layers are also considered for thermal analysis.

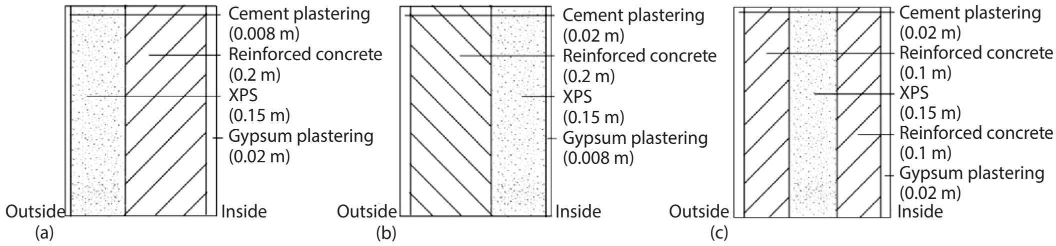

Figure 1. Multilayer wall types [7]; (a) exterior wall insulation, (b) interior wall insulation, and (c) sandwich wall insulation

Thermal insulation thickness is obtained based on the Association for Environment Conscious Building guidelines, which is a network for promoting sustainable buildings [38]. These classifications are arranged based on CO_2 emissions and predicted energy use. The wall overall heat transfer coefficient (U-value) described as the Silver Standard which is 0.25 W/m^{2}K. Depending on this value, an insulation thickness of 0.15 m was applied according to numerical calculations made for the exterior, interior, and sandwich wall applications.

Table 2. The thickness and thermophysical properties of the wall materials [31, 37]

Material name	Thickness [m]	Thermal conductity [Wm^{-1}K^{-1}]	Specific heat [J^{-1}kg^{-1}K^{-1}]	Density [kgm^{-3}]
Outside gypsum plastering	0.008	0.720	840	1860
Insulation material (XPS)	0.15	0.035	1400	35
Reinforced concrete	0.2	2.300	1000	2300
Inside gypsum plastering	0.02	0.380	1090	1120

A set of mathematical equations are formulated in an in-house developed software code to calculate the heat loss/gain through walls. In appendix, fig. A shows the flowchart of numerical evaluation of a model for transient, 1-D heat conduction visual basic (VB) programming. This is a standard root-finding problem in VB program. To evaluate the implicit finite difference equation a large number of roots must be available. First input and output items based on climatic data and inside condition data are defined in code (in fig. A numbered I). After data input and output for temperature distribution and heat transfer values operations, each wall materials' thermophysical properties are given in second step (II). These are ρ is the density, c_p – the specific heat, k – the thermal conductivity, $\propto$ – the heat diffusivity is defined $k/\rho\ c_p$. In next step, α and σ and ε are given. And these values are (III):

– absorption coefficient, α ,
– Stefan-Boltzmann constant, σ,
– emissivity of the emitting surface, ε,
– once you have entered the values, time and grid steps are determined (IV); grids are generated that according to different wall models; these identifications are:
  – grid line spacing are associated is 0.001 m.
  – time step help within a while loop so, time step size is assumed that 2 minutes for one day has 720 steps.

Solving the problem, FOR. NEXT loops are identified with input files, (V). And a simple loop has gone around the loop, each time loop variable is changed. On this structure allows to repeat the statements in a loop until the condition is True or until it becomes True, a specified number of times, or once for each data in a calculation in numbered (VI) and (VIII). Before the statement loops again, the temperature distribution through the wall is calculated in numbered (VII). In consequences of these following iteration steps over and over again temperature distribution through the wall, heat energy storage and heat flux values to/from the inside and outside surfaces are printed in number (IX).

Statistical analysis

Four categorical variables were used as input in the factorial design in this study. 1-D time-dependent heat conduction equation is solved by implicit finite difference method for monthly average daily climatic conditions and is analyzed for three different directions including north, south, and west orientations. Another factor is the position of insulation material which is either an exterior, interior or center position. The inside temperature is defined as a constant value for the chosen climatic conditions (January, April, and July). Each factor is studied at 3 different levels and hence the selected design is 3^4 full factorial design. Figure 2, explains a visual representation map of the structure of a network with a variety of levels and factors with different line connections. This designed plan of experiments helps cover almost all possible combinations of factor levels. The power of the factorial design is derived from this capability to weigh all possible combinations. Results obtained from the experiments are analyzed by either a spreadsheet or a commercially available software DESIGN EXPERT [39].

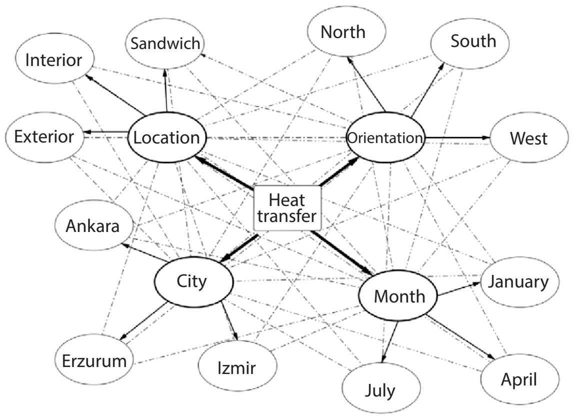

Figure 2. Network diagram of 3^4 factorial experimental design

Table 3. The 3^4 full factorial experiment pattern sample

Run	Treatments				Response
	City	Orientation	Location	Month	Heat transfer [Whm^{-2} per day]
1	Erzurum	South	Exterior	January	144.6
2	Erzurum	South	Exterior	April	–78.1
3	Erzurum	South	Exterior	July	–8.6
4	Erzurum	South	Interior	January	–144.1
5	Erzurum	South	Interior	April	–76.5
6	Erzurum	South	Interior	July	–7.1
7	Erzurum	South	Sandwich	January	–143.3
8	Erzurum	South	Sandwich	April	–76.1
9	Erzurum	South	Sandwich	July	–7.2
10	Erzurum	West	Exterior	January	–148.9

Solar and sky radiation, outside temperature, relative humidity, heat convection coefficient defined by wind velocity values for the outside surface are also expressed as a function of time. Numerical analyses under these climatic conditions are carried out to calculate time-dependent temperature distribution through the wall and the heat transfer by using the meteorological data for Erzurum, Ankara, and Izmir which are the cities used for calculations due to their different climatic conditions. One would need to run 81 treatment combination complete the experimental study. Table 3 shows the first 10 test conditions the last column of which is the heat transfer through the wall as computed by the VB code developed in-house by the authors. The complete list of test conditions is not given here for the sake of brevity in the manuscript. But the list is available in the Appendix, tab. A.

Building the factorial design

A research project usually involves the following steps: a listing of all possible factor effects, screening of the more important factor effects, and optimization of the selected factor-response relations by a response surface model and finally validation of the results to identify the size of error [40, 41]. It is important to identify potentially important factors for a successful experiment. This requires prior theoretical knowledge to separate those factors that are less important and not worth the effort to study so limited research resources are saved. Hence the number of potential factors is reduced to a reasonable number. The next step is to set an experimental range and an appropriate level for each factor. This step is important because using an inappropriate experimental range or inappropriate factor levels generally result in poor experimental results difficult to analyze. Once all factors and experimental domains are identified, the next step is to prepare a list of experiments to be performed [42].

Analysis of variance

A total of 81 experimental runs are done and the results are fed to DESING EXPERT software to calculate the ANOVA table as shown in tab. 4. The letters A, B, C, and D designate the factors city, orientation, location and month of the year, respectively. The AB signifies the interaction between the factors city and orientation. In this table the degrees of freedom, the sum of the squares of the variance of the individual effect and mean square and p-values are shown.

Table 4. The ANOVA table, r^2: 0.999952

Source	Sum of squares	Degrees of freedom	Mean square	F-value	p-value
A-city	56022.6	2	28011.3	123000	< 0.0001
B-orientation	508	2	254	1117.3	< 0.0001
C-location	14.6	2	7.3	32.2	< 0.0001
D-month	203000	2	102500	446000	< 0.0001
AB	16.64	4	4.16	18.3	< 0.0001
AD	3703.2	4	925.8	4072.8	< 0.0001
BD	166.8	4	41.7	183.6	< 0.0001
CD	3.8	4	0.95	4.2	0.0048
Residual	12.8	56	0.23		
Cor total	263448	80			

In this study, only main effects and two-factor interactions are considered. Figure 3 shows that the Shapiro-Wilk test which is a way to tell the absolute value of all effects if a random sample comes from a half-normal distribution. It can be seen from fig. 3 that the factors D, A, AD, and B are more significant factors as they deviate more from the line. Those factors that are lined up along or close to the line are less significant or insignificant factor effects. Same conclusions can be also observed from the ANOVA table in tab. 4. Those more important factor effects have the smallest p-values less than the initially determined level of significance of 0.05. The overall model is also significant.

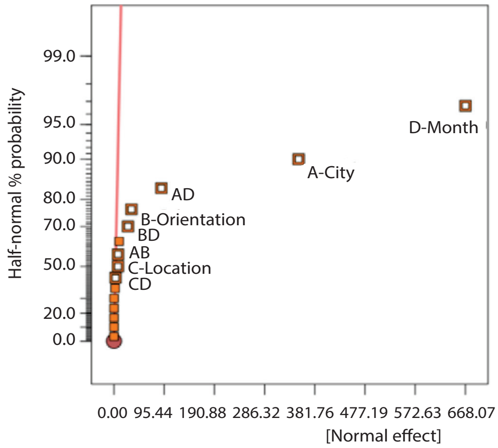

Figure 3. Half-normal plot (Shapiro-Wilk test)

Discussion

Before beginning work on the manuscript, the authors had a code which would calculate the heat loss/gain through walls if fed by input factors like city, orientation, location and month [7]. However, this code was unable to relate between the factors or tell which factor has a significant effect on the response variable (heat loss/gain). Statistical experimental design, therefore, provided the authors with a method to check which factors are significantly affecting the response, which two-factors are interacting, and so on. The very low p-values for factors A, B, C, D, AB, AD, BD, and CD mean that these factors and two-level interactions are all significant. All factors are effective in producing a change in the response. Finally, it can be said that the statistical experimental design used in this study allowed us to identify if there is any factor effect that is insignificant (AC, BC) on the response. The ANOVA results act like filters of factors affecting energy consumption in buildings. When a factor stands out (is significant) proper precautions can be taken to counteract to minimize energy consumption. For example, decisions for locating the insulation location can be made based on the results of ANOVA. The AC and BC terms being insignificant can be interpreted as the location of insulation not making a difference in different cities or orientations.

Another utility of this method is that it enables the researcher to obtain a polynomial equation that may predict the effects of input factors on the response. In this study, a polynomial equation is also obtained but is not used here for prediction in the form of sensitivity analysis because the factors were all categorical prohibiting any possibility for interpolation. If numeric variables were chosen as input factors, the model very well could have been used for sensitivity analysis. When the more important factor effects are identified by this technique, this information can be used in the design of new buildings for improved and more energy efficient construction.

Conclusion

A set of mathematical equations are formulated in an in-house developed software code to calculate the heat loss/gain through walls if independent variables like city, orientation, location and month are fed at differing levels. A statistical experimental design methodology is used in this study to determine the relationships between the factor effects and the response variable. A 3^4 full factorial experimental design is set up with a total of 81 runs covering all possibilities within the range of factor effects. The ANOVA table showed that all four independent variables and their two-factor interaction terms (except AC and BC) are significant at 0.95 level of significance. Because the variables are categorical the resulting polynomial model could not be used for prediction. The mathematical model could calculate the response variable at differing combinations of the input factors but could not identify them whether they are significant or not. This shows us the utility of experimental design in that it enables researchers if a factor or its interaction with other factors are significantly effective in causing a change in the response.

Appendix

Table A. The 3^4 full factorial experiment results

Run	Treatments				Response	Run	Treatments				Response
	City	Orientation	Location	Month	Heat transfer (Wh/m^{2}day)		City	Orientation	Location	Month	Heat transfer (Wh/m^{2}day)
1	Erzurum	South	Exterior	January	-144.6	42	Ankara	West	Interior	July	25.5
2	Erzurum	South	Exterior	April	-78.1	43	Ankara	West	Sandwich	January	-103.6
3	Erzurum	South	Exterior	July	-8.6	44	Ankara	West	Sandwich	April	-41.8
4	Erzurum	South	Interior	January	-144.1	45	Ankara	West	Sandwich	July	25
5	Erzurum	South	Interior	April	-76.5	46	Ankara	North	Exterior	January	-106.9
6	Erzurum	South	Interior	July	-7.1	47	Ankara	North	Exterior	April	-48.8
7	Erzurum	South	Sandwich	January	-143.3	48	Ankara	North	Exterior	July	18
8	Erzurum	South	Sandwich	April	-76.1	49	Ankara	North	Interior	January	-107
9	Erzurum	South	Sandwich	July	-7.2	50	Ankara	North	Interior	April	-48.1
10	Erzurum	West	Exterior	January	-148.9	51	Ankara	North	Interior	July	18.3
11	Erzurum	West	Exterior	April	-77.7	52	Ankara	North	Sandwich	January	-106.2
12	Erzurum	West	Exterior	July	-5.2	53	Ankara	North	Sandwich	April	-47.9
13	Erzurum	West	Interior	January	-148.6	54	Ankara	North	Sandwich	July	18
14	Erzurum	West	Interior	April	-76.1	55	Izmir	South	Exterior	January	-55.3
15	Erzurum	West	Interior	July	-3.6	56	Izmir	South	Exterior	April	-18.6
16	Erzurum	West	Sandwich	January	-147.7	57	Izmir	South	Exterior	July	40.6
17	Erzurum	West	Sandwich	April	-75.6	58	Izmir	South	Interior	January	-55
18	Erzurum	West	Sandwich	July	-3.6	59	Izmir	South	Interior	April	-17.6
19	Erzurum	North	Exterior	January	-151.1	60	Izmir	South	Interior	July	42
20	Erzurum	North	Exterior	April	-81.3	61	Izmir	South	Sandwich	January	-54.7
21	Erzurum	North	Exterior	July	-11.1	62	Izmir	South	Sandwich	April	-17.6
22	Erzurum	North	Interior	January	-150.9	63	Izmir	South	Sandwich	July	41.4
23	Erzurum	North	Interior	April	-80	64	Izmir	West	Exterior	January	-62.2
24	Erzurum	North	Interior	July	-9.8	65	Izmir	West	Exterior	April	-19.6
25	Erzurum	North	Sandwich	January	-150	66	Izmir	West	Exterior	July	43.1
26	Erzurum	North	Sandwich	April	-79.6	67	Izmir	West	Interior	January	-62.2
27	Erzurum	North	Sandwich	July	-9.8	68	Izmir	West	Interior	April	-18.6
28	Ankara	South	Exterior	January	-99.3	69	Izmir	West	Interior	July	44.8
29	Ankara	South	Exterior	April	-42.1	70	Izmir	West	Sandwich	January	-61.8
30	Ankara	South	Exterior	July	22.3	71	Izmir	West	Sandwich	April	-18.5
31	Ankara	South	Interior	January	-99.1	72	Izmir	West	Sandwich	July	44.3
32	Ankara	South	Interior	April	-41.1	73	Izmir	North	Exterior	January	-65.3
33	Ankara	South	Interior	July	22.6	74	Izmir	North	Exterior	April	-25.4
34	Ankara	South	Sandwich	January	-98.5	75	Izmir	North	Exterior	July	37.8
35	Ankara	South	Sandwich	April	-40.9	76	Izmir	North	Interior	January	-65.3
36	Ankara	South	Sandwich	July	22.2	77	Izmir	North	Interior	April	-24.8
37	Ankara	West	Exterior	January	-104.3	78	Izmir	North	Interior	July	38.9
38	Ankara	West	Exterior	April	-43	79	Izmir	North	Sandwich	January	-64.9
39	Ankara	West	Exterior	July	24.8	80	Izmir	North	Sandwich	April	-24.7
40	Ankara	West	Interior	January	-104.3	81	Izmir	North	Sandwich	July	38.4
41	Ankara	West	Interior	April	-42						

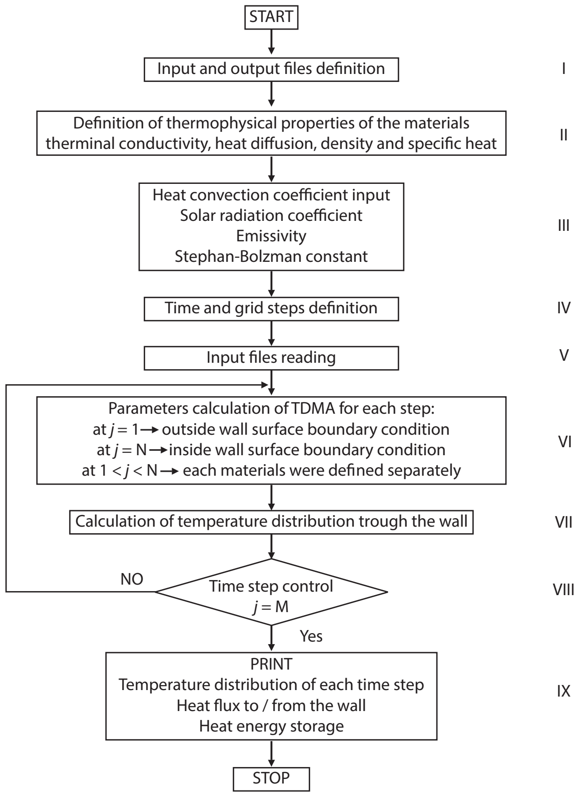

Figure A. Design of visual basic flowchart

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