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Simulation of Thermal Load of A Restaurant's Building at Sebha City to Which Simple Passive Techniques Were Applied

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Abstract The simulation of possible heating and cooling requirements of restaurant's building has been presented in this paper, when simple Thermal Passive Techniques (TPT) such as Building materials selection, Insulation, and careful design of the doors and windows have been applied to building's construction in Sebha city at the Libyan south. The known software for dynamic simulations (TRNSYS 16) has been used as an environment of digital experimentation for this study. A model represents the building has been constructed with the help of the available model of the Multi-zone Building modeling with Type56 and TRNBuild. The thermal load on building's construction with TPT (such as the control of building materials, insulation, shading, infiltration and ventilation with window resizing) has been calculate under weather conditions of a Typical Meteorological Year (TMY) of Sebha city . The simulation has been conducted successfully, where good result of heating and cooling demands during JAN month of the building has been obtained. The maximum about (21571 KJ/hr) of heating load for dining room, (34 KJ/hr) of heating load for kitchen, (12046 KJ/hr) of cooling load for kitchen and didn't has any thermal load for storage room.

Key words: TRNSYS 16 , Heating load, Cooling load, Simulation, Passive technologies.

محاكاة الحمل الحراري لمبنى مطعم في مدينة سبها مطبق عليه التقنيات الحرارية السلبية البسيطة

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الملخص تقدم الورقة محاكاة لمتطلبات التدفئة و التبريد الممكنة لمبنى مطعم، عند تطبيق التقنيات الحرارية السلبية البسيطة مثل اختيار مواد البناء و العزل والتصميم الدقيق للأبواب و النوافذ على المبنى في مدينة سبها في الجنوب الليبي، حيث تم استخدام البرنامج المعروف للمحاكاة الديناميكية (TRNSYS 16) كبيئة للتجربة الرقمية لهذه الدراسة. نموذج يمثل المبنى الذي تم بناؤه بمساعدة النموذج المتاح لمحاكاة المباني متعددة المناطق باستخدام Type56 و TRNBuild. تم حساب الحمل الحراري على مكونات المبنى مع تطبيق التقنيات الحرارية السلبية البسيطة (مثل التحكم في مواد بناء المستخدمة، العزل، التظليل، التسريب والتهوية مع تغيير حجم النافذة) في ظل الظروف الجوية للسنة النموذجية للأرصاد الجوية (TMY) لمدينة سبها. حيث تم إجراء المحاكاة بنجاح، وتم الحصول على نتيجة جيدة لمتطلبات التدفئة والتبريد خلال شهر يناير من المبنى. حيث كانت أقصى حمولة تسخين لغرفة الطعام (21571 كيلو جول / ساعة) ، (34 كيلو جول / ساعة) من حمل التدفئة للمطبخ ، (12046 كيلو جول / ساعة) من حمل التبريد للمطبخ، و لا يوجد أي حمولة حرارية لغرفة التخزين.

الكلمات المفتاحية: TRNSYS 16، حمل التدفئة، حمل التبريد، المحاكاة، التقنيات السلبية.

1. Introduction

The climate in Sebha city at the south of Libya is mostly dry and moderately cold in winter, while it is quite dry and extremely hot in summer Ref. to Sebha Annual Weather Data Reports [1, and 3].

Under such conditions and for comfortable functioning in the living spaces there is an important need to control indoor temperature (increased in winter and decreased in summer) and simultaneously, keeping comfortable level of humidity . In this context, the main problem facing the building style currently applied in most Libyan cities and especially at the South region is the absence of thermal consistency between the buildings and the environment. The wide use of walls of hollow concrete blocks and heavy concrete roofs without any kind of insulation, the use of non proper sizing and glazing of windows, the lower levels or even the lack of shading during summer additional to the random building orientation and the ignorance of the prevailing wind streams additional to the missing of any ventilation control, all these factors causes the evident residents discomfort additional to the non-reasonable consumption of expensive energy for air conditioning.

The most important goal that should be taken into consideration when start dealing with energy conservation in buildings is to keep the levels of energy loss or gain from or to the building – depending on the season requirements - at optimum level, using low cost technology as possible. Based on this logic, it is very necessary to have a clear view about the extent of the possible can be calculate the thermal load which used the so called Thermal Passive Technologies (TPT) [4].

The simplest of these techniques may be the choice of building materials and orientation, the application of the correct size of doors and windows, the application of insulations, shading and infiltration control, the adoption of suitable ventilation strategies. The TPT may be introduced as a typical method to have an economical solution. Through the application of an economically optimum TPT in buildings higher standards of health and thermal comfort may be achieved. Through this research, and before any serious application of active delivery of heating or cooling to living space, the first step is to check the effectiveness "thermally at least" of any possible application of TPT, where, in spite of their negligible effective running cost; their capital costs may be high. Therefore, care must be taken to avoid wasting the savings on electrical heaters or air conditioners by using of costly TPT. To estimate the thermal load of the TPT via experimental field studies, one must spend much money and plenty of time.

The known software for dynamic simulations (TRNSYS 16) has been used as an environment of digital experimentation for this research [5].

By simulation using TRNSYS16 (Klein et al. [5], SEL [ii] and CSTB [i]) - at relatively low cost and comparably shorter time - it was possible to make a calculate of the thermal load behavior of a restaurant building constructed with TPT during JAN month at Sebha city.

2. System models

The heating requirements of a restaurant will be considered. The restaurant consists of three zones: the dining room, the kitchen, and a storage area. A floor plan of the building is shown in Figure (1). The dining room faces directly south and has a large double-glazed window. General data concerning the restaurant is as follows:

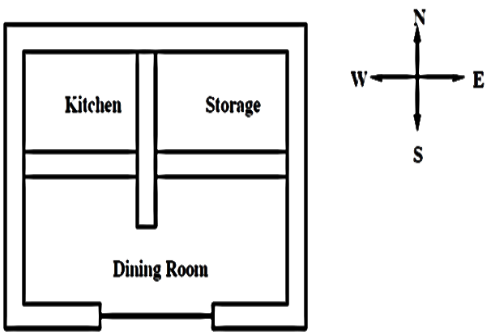

Figure (1) Floor Plan of Restaurant

There are two types of walls: exterior and interior. The floor consists of a concrete slab on the ground, an insulation layer and stone tiling. The only window, located in the dining room, has two glazings. The flat roof has the following structure (from inside to outside):

plaster board, air gap, insulation, concrete, roofing. The heat transfer coefficient at the outside of the exterior walls and roof varies with the wind speed. Note that the heat transfer coefficient of the floor is set to a very small value since we want to impose the surface temperature to be equal to the ground temperature [6].

2.2. Air Flows

The infiltration rate is fixed at a half an air change per hour during un-occupied times. For the dining room, there is an additional infiltration that follows the influx of customers and reaches a maximum of a quarter of an air change per hour. Part of this extra infiltration is considered to flow from the dining area to the kitchen. The maximum convective coupling from the dining room to the kitchen is 25 kilograms per hour. The kitchen is also ventilated during working hours at a rate of a half of an air change per hour [6].

2.3. Gains

There are gains from people and lights in both the dining room and kitchen. The kitchen also has gains associated with the stoves. The lights are on whenever the building is occupied. The schedule of customers differs for weekdays and weekends. The storage room has fixed gains from a freezer [6].

2.4. Heating

The kitchen and dining room are maintained at 20 degrees Celsius during occupied hours and at 15 degrees other times. The storage area is unheated [6].

2.5. Cooling

A small room air conditioner is located in the kitchen which turns on if the temperature rises above 25 degrees Celsius [6].

Suitable components Multizone Building modeling with Type56 and TRNBuild from the simulation program TRNSYS 16 were used to represent the previously mentioned building, the calculate Heating/Cooling demands has been evaluated by studying the thermal interaction of the restaurant building with TPT and the environment. The TPT of the restaurant building includes (The selection of less conductive building materials, fitting of insulations, resizing the windows with the installation of selective double glazing, controlling of ventilation, controlling of infiltration and providing more shade). The aim of this process is to offer comfortable indoor conditions (15 to 20 °C indoor temperatures and 0.0075 relative humidity).

3. Simulation procedures

The mentioned restaurant building case were constructed using the available TRNSYS 16 components 'Types' as shown in Figures 1, where various system models for input, processing and output of data are presented.

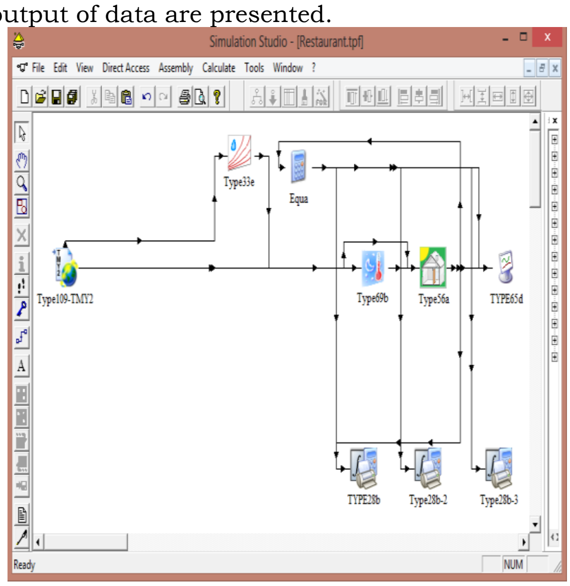

Figure (2) Graphical interface of the Multizone Thermal Zone represents the project of Sebha restaurant Building with TPT

An appropriate control of building thermal properties (i.e. conductance, emittance, reflectance, transmittance, absorptance, and diffusivity) for walls, floor and roof has been performed through the use of selective building materials and the process has been expressed in TRNSYS 16 via component parametrical modifications. The associated thermal properties that affect the indoor air were also controlled within the possibilities offered by TRNSYS components to reflect the thermal conditions inside the restaurant building in Sebha [4].
Because the weather data of the TMY should represent as possible near real climatic conditions at the site, the TMY as presented by Domanski and Azzain [2] has been applied to the building structure to produce realistic thermal profiles for the House-Office building in Sebha. This TMY is used as forcing function to simulate the impact of the weather conditions on the temperature levels and the humidity ratio inside the restaurant building.
Due to the large number of models involved in this simulation process it is not convenient to present their mathematical descriptions. Nevertheless, their details can be found in the TRNSYS 16 manual. The general fundamentals of the thermal load calculations are derived basically from transfer function approach as described in ASHREA Handbook of Fundamentals 2001 [2].

4. Mathematical Description of Type 56

The general case, which does not include the simplified model of the heating and cooling equipment is presented first. If separate equipment components are used, they can be coupled to the zones as either internal convective gains or ventilation gains. Following this, the simplified method of providing heating and cooling equipment within the TYPE 56 component is described.
The Thermal Zone of building model in TYPE 56 is a non-geometrical balance model with one air node per zone, representing the thermal capacity of the zone air volume and capacities which are closely connected with the air node (furniture, for example). Thus the node capacity is a separate input in addition to the zone volume [6] .

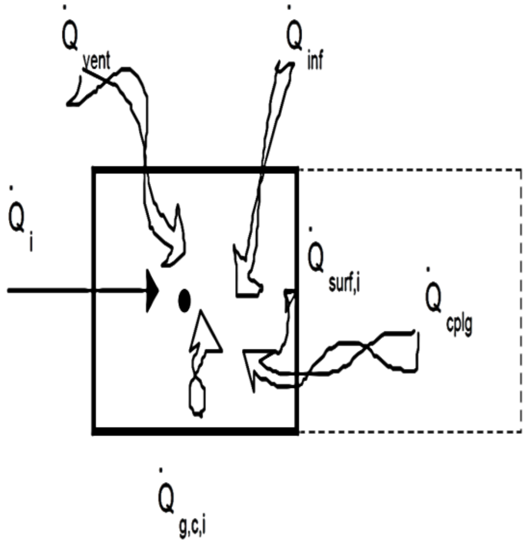

Figure (3) Heat balance on the zone air node

The followed some mathematical equations:

4.1. Convective Heat Flux to the Air Node:

$$\dot{Q}_i = \dot{Q}_{surf,i} + \dot{Q}_{inf,i} + \dot{Q}_{vent} + \dot{Q}_{g,c,i} + \dot{Q}_{cplg,i} \quad (1)$$

where $\dot{Q}_{surf,i}$ is the infiltration gains (air flow from outside only)

$$\dot{Q}_{inf,i} = \dot{V}\cdot\rho\cdot c_p\cdot(T_{outside} - T_{air}) \quad (2)$$

$\dot{Q}_{vent,i}$ is the ventilation gains (air flow from a user-defined source, like an HVAC system, given by

$$\dot{Q}_{vent,i} = \dot{V}\cdot\rho\cdot c_p\cdot(T_{ventilation,i} - T_{air}) \quad (3)$$

$\dot{Q}_{g,c,i}$ is the internal convective gains (by people, equipment, illumination, radiators, etc.), and

$\dot{Q}_{cplg,i}$ is the gains due to (connective) air flow from zone I or boundary condition, given by

$$\dot{Q}_{cplg,i} = \dot{V}\cdot\rho\cdot c_p\cdot(T_{zone,i} - T_{air}) \quad (4)$$

4.2. Coupling:

The coupling statement allows the definition an air mass flow a zone receives from another zone, considered as a heat flow from or to the air node. The statement does not automatically define the air flow back to the adjacent zone as would occur in an interzonal air exchange [6] .

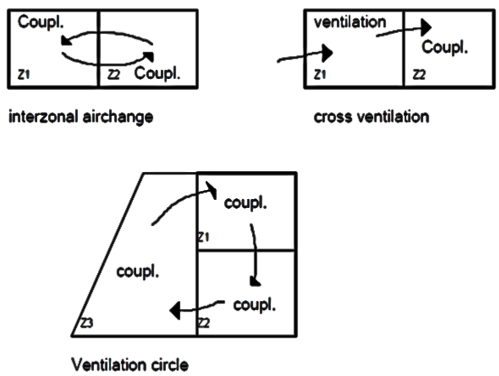

Figure (4) coupling statement

4.3. Radiative Heat Flows (only) to the Walls and Windows:

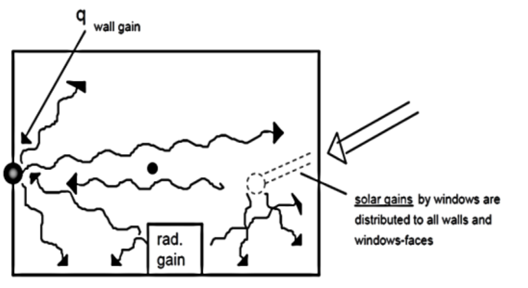

Figure (5) Radiative energy flows considering one wall with its surface temperature node

$$\dot{Q}_{r,w_i} = \dot{Q}_{g,r,i,w_i} + \dot{Q}_{sol,w_i} + \dot{Q}_{long,w_i} + \dot{Q}_{wall-gain} \quad (5)$$

where $\dot{Q}_{r,w_i}$ is the radiative gains for the wall surface temperature node, $\dot{Q}_{g,r,i,w_i}$ is the radiative zone internal gains received by wall, $\dot{Q}_{sol,w_i}$ is the solar gains through zone windows received by walls, $\dot{Q}_{long,w_i}$ is the longwave radiation exchange between this wall and all other walls and windows ($\varepsilon_i = 1$), and $\dot{Q}_{wall-gain}$ is the user-specified heat flow to the wall or window surface. All of these quantities are given in kJ/h.

4.4. Total Gains from Surfaces in a Zone:

The total gain to zone i from all surfaces is the sum of the combined heat transfers [6].

$$\dot{Q}_{surf,i} = \sum A_s \dot{q}_{comb,i} = \sum_{j=1}^{Adj\ Zones} \sum_{i=1}^{surface\ in\ j} A_s B_s T_{star,j} + \sum^{ext\ surfaces} A_s B_s T_a + \sum^{int\ walls} A_s B_s T_{star} + \sum^{known\ bound} A_s B_s T_{b,s} - \sum^{surface\ in\ zone\ i} A_s (C_s T_{star,i} - D_s - S_{s,i}) \quad (6)$$

where A_s is the inside area of surface s.

Both sides of an internal wall are considered as inside surfaces and must be included twice in

An energy balance on the star node :

$$\dot{Q}_{surf,i} = \frac{1}{R_{star,i}} (T_{star,i} - T_i) \quad (7)$$

Any more information about equation 6 to the express the inside surface heat flux for an external wall as a function of the boundary air temperatures, and The long-wave radiation exchange between the surfaces within the zone and the convective heat flux from the inside surfaces to the zone air are approximated using the star network refer to reference [6].

5. Simulation Results

The energy control system inside the restaurant building has been set to start heating if T_{set} < 15 ˚C and start cooling if T_{set} > 20 ˚C, where T_{set} is the set point temperature. Simultaneously the same control keeps relative humidity at 0.0075.

Figure 6, 7, and 8 shows the calculated integrated changes of thermal loads during winter season January.

The maximum values of the calculated heating and cooling loads for the conventional restaurant building with TPT of Sebha are respectively 21571 KJ/hr for heating dining room figure 3, 34.49 KJ/hr for heating kitchen figure 7, 12046 KJ/hr for cooling kitchen figure 8, and The storage area is unheated and didn't have cooling load in this month.

Generally, it is clear that the highest load at the site is the heating load which covers large period of JAN month in the dining room.

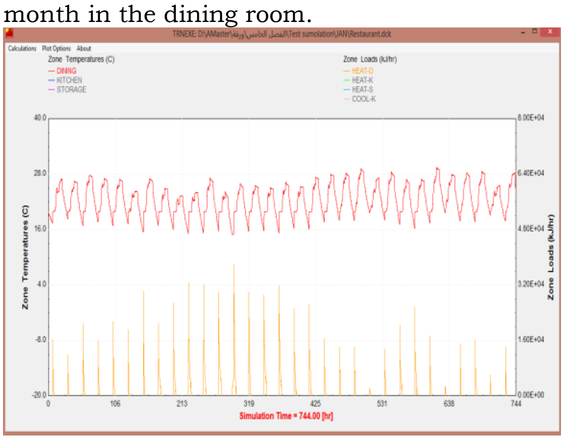

Figure (6) heating load of dining room

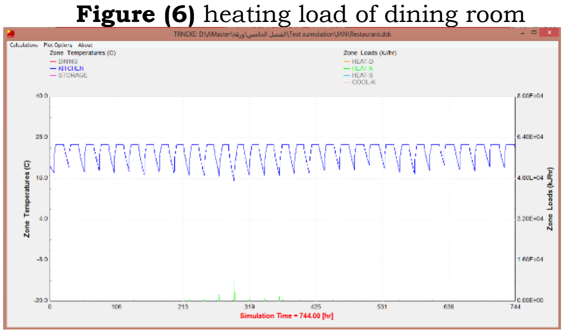

Figure (7) heating load of kitchen

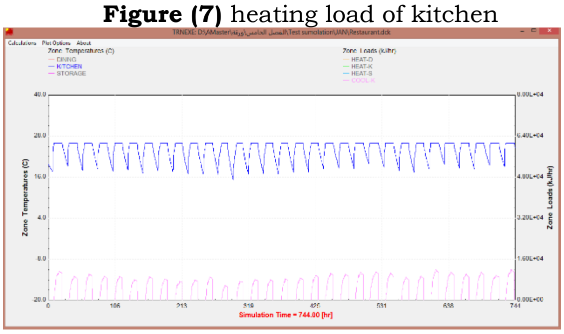

Figure (8) cooling load of kitchen

6. Conclusions

From the simulation about 21571 KJ/hr of maximum energy demand for heating in the dining room and 12046 KJ/hr of maximum energy demand for cooling.

There are several general achievements of this research which may be presented as follows:

The choice of the most suitable building materials has significant importance as first step towards the successful implementation of the TPT. The second thing is to control the infiltration and applying effective optimal ventilation strategy. The positive effect of shading and un-shading is also an important factor that should be optimized to offer useful results for the building by solar heating in winter and insulation prevention in summer, The control of ambient temperature and humidity around buildings should have the priority when comfortable indoor conditions have to be achieved.

The creation of optimum microclimate (i.e. year-around controlled outdoor conditions at the buildings nearby areas) may be performed by the application of several methods. Among these methods for cooling are the trees implantation, the creation of green areas as much as possible, construct and operate in an optimum manner various kinds of fountains and choosing the optimum building positioning to make use of the prevailing winds while achieving optimum use of insulation and shading with building overheat prevention. Since that the heating season in the research area is need more heating load therefore, the use of the TPT may offer good results to reduce the heating load. We also recommend calculating the thermal load of the restaurant building without applying the negative thermal techniques and then making a comparison between them.

Acronyms

(TPT), Thermal Passive Technologies.

(TMY), Typical Meteorological Year.

References

[1]- Annual Data-general Report (1965-1988), Annual Data-detailed Reports (1981, 1984, 1985, 1986, 1987 and 1988), Office of Meteorological Measurements, Sebha City, Libya.

[2]- ASHREA Handbook of Fundamentals 2001.

[3]- Domanski, R., Azzain, G., “Generation of First Typical Meteorological Year (TMY) for Sebha City”, Bulletins of Institute of Heat Engineering (IHE), Polytechnic Warsaw (PW). Poland 2003.

[4]- Elowa, M.I., Ali, Rasem. A., “Sebha Solar House a Prototype for Solar Energy Utilization”, Libya, International Conference of Energy Systems, 2000, ICES, 2K, Amman- Jordan 25-28 Sep. pp 142-164.

[5]- Gassem Azzain, “’TRNSYS 16’ a Complete Digital Experimentation Platform and Simulation Studio for Transient Systems and Intelligent Buildings”. The Journal of Sebha University for applied Sciences. Oct. 2010,. Sebha Libya.

[6]- Simulation Program, “TRNSYS 16”, Multizone Building modeling with Type56 and TRNBuild, (Volume 6 of the TRNSYS documentation).

Related Web sites

[1]- Centre Scientifique et Technique du Batiment « the Centre for Scientific Research in Buildings », CSTB-France, Access on (5-1-2020) : http://software.cstb.fr

[2]- Solar Energy Laboratory SEL, Developer of (TRNSYS) source code the TRaNsient SYtems Simulation Program, Access on (1-1-2020) : http://sel.me.wisc.edu/trnsys/default.htm