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Comparative Tests of Thermal Modeling Computer Program - Ecotect vs. TAS

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Abstract

Various tests are conducted to investigate and compare how both programs (Ecotect and TAS) consider various parameters which affect buildings' thermal performance including thermal mass, ventilation, and solar gain. The thermal mass comparative tests revealed that the internal air temperature predicted by TAS is higher than that of Ecotect particularly with large thermal mass. A significant difference is observed in the fabrics loss/gain estimated by TAS and that estimated by Ecotect for various fabrics thicknesses in the cases of both free-running and air-conditioning. Further, the fabrics loss/gain estimated by Ecotect in the case of air-conditioning is the same as that in the case of free-running. The solar gain comparative tests indicate that the magnitude of solar gain estimated by TAS is almost two times that estimated by Ecotect. Ecotect does not consider the internal solar absorption of the fabrics in estimating the solar gains, while according to TAS simulation; greater solar gain is associated with higher internal solar absorption of fabrics. Moreover, the ventilation load according to Ecotect rises steadily with the increase of the ventilation rate, while in TAS; the magnitude of increase in the ventilation load fades significantly with higher ventilation rate. Additionally, the ventilation load estimated by Ecotect is extremely higher than that estimated by TAS. In Ecotect, the fabrics loss/gain was found constant for various air change rates. Conversely, in TAS, the fabrics loss/gain decreases with the increase of ventilation rate.

Keywords: Building Thermal Simulation, Computer Modeling, Ecotect, TAS, Thermal Mass, Ventilation.

1. Introduction

As computers can run the most sophisticated calculations, computer simulation became a powerful tool to analyze dynamic thermal performance of buildings including predicting the hour-by-hour variations of internal conditions, heat fluxes, and energy usage in response to occupancy patterns, plant schedules, and weather conditions. Computer simulation is significantly constructive when measurement methods are too expensive or not available. However, the validity of the results of the simulation depends on the quality of the program used [1]. Several thermal modeling programs are available in the market ranging from simple to comprehensive ones. Relatively simple programs have been produced which use basically the steady-state type calculations. A number of programs are based on the "admittance procedure" which analyze the dynamic thermal response, but in a strict sense. Other programs use sophisticated calculation methods for dynamic thermal response. Besides, some computer modeling programs are more suitable to simulate buildings with specific features. For instance; some programs are designed for commercial buildings (such as BUNYIP) and others are only suited to air-conditioned buildings (such as EnergyPlus) [2]. Therefore, the characteristics of the buildings could affect the selection of the most appropriate thermal modeling program. Further, criteria should be applied in choosing the most appropriate thermal modeling program for a particular study. These criteria are as follows:

a) **Required Outputs:** The first and most important criterion in selecting thermal modeling program is the capability of the program to deal with the required application as well as to provide the basic needed outputs.

b) **Accuracy:** As a general strategy, it would seem reasonable to aim for a high level of accuracy. The accuracy of the various programs should be checked

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through; identifying the thermal analysis calculation method on which a program is based, considering the limitations of each program, and assessing the level of modeling details demanded by the program as input data. The levels of details required by various simulation programs are different. Part of the input data of the simulation is sometimes fixed or hidden from the user. For example, in Hevacomp software some of thermal properties of construction materials provided in the fabric data interface are allowed to be edited, while other properties such as thermal conductivity and specific heat are hidden.

c) **Simplicity and Ease of Learn and Use:** Building energy simulation tools require a great deal of time to learn [3]. The ease of learning a program is influenced with; the quality of its user's manual, the availability of a support system to answer questions, as well as the complexity of input procedures. After gaining sufficient experience, the need to obtain and enter a complex set of input data into simulation programs continues to consume the time. Many packages can access data libraries which assist in preparing the needed inputs. In the case of several buildings are to be entirely simulated, simplicity to deal with the computer program should be considered in selecting the appropriate one. However, it is impossible to achieve the optimum level of comprehensiveness and ease of use in the field of building thermal simulation [4]. Consequently, thermal modeling program should be selected with the intention of finding a balance between ease of application and comprehensiveness with emphasis on the minimum required outputs.

d) **Access to Program:** In order for potential program to be selected, demonstration versions of the program should be obtained and run. Manuals for the most suitable programs should be obtained and reviewed. Afterwards, demonstration versions of these programs should be obtained in order to run some tests. Some of programs may have to be excluded from selection, not because of their capabilities, but because they are so expensive to purchase.

2. Selection of Thermal Modeling Computer Program for the Comparative Tests

This paper is part of a study conducted on naturally ventilated residential buildings located in crowded built environment. In that study, the selected program had to be at least capable of predicting the internal conditions such as temperature and humidity, estimating the heating and cooling loads, assessing the thermal comfort, and examining the performance of alternative constructions to achieve better indoor thermal environments and lower energy consumption. A brief literature survey of some of the commonly used building simulation programs was done. According to the main characteristics of the studied buildings and according to the above discussed criteria, three thermal modeling program are firstly selected for deep investigation and for the comparative tests, which are; Ecotect v5.60, TAS (Thermal Analysis Software) v9.1.4.1, and Bentley Hevacomp V8i. Training on using these programs for simulation was taken place until sufficient experience was gained which enabled the researcher to carry out the required modeling. However, it is discovered that Hevacomp, although it is widely used, does not consider shading on opaque materials. This is clarified by a test conducted on a free running windowless cube (9*9*9 meter) surrounded by neighboring cubes. The internal temperature and the fabrics loads of the cube were calculated once with external shadings and once without them. The results showed no difference between the two cases in terms of internal temperature, fabric load, or total load (see figure 1).

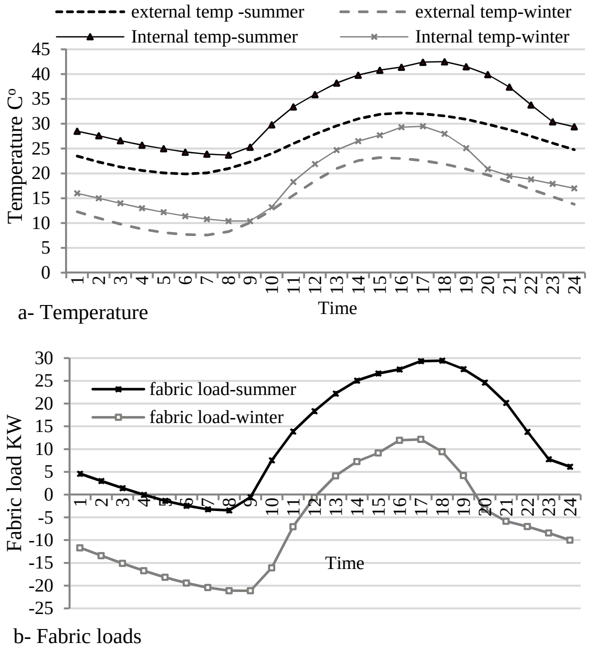

Fig 1 Temperature and fabric loads of a free running windowless cube, with and without surroundings

Therefore, the researcher contacted the support team of Bently Hevacomp to ask whether the software considers the external shading on the opaque components of buildings. The technical support analyst at Hevacomp confirmed that "*The shadows object only affect the direct solar component on glazing*". If the building to be simulated is located in crowded built environment and shaded by neighboring buildings most of the time, the selected program should consider shading on the opaque and the glazing components of the buildings as an absolute requirement, regardless of any other factors. Consequently, Hevacomp software is excluded, where comparative tests are conducting using Ecotect and TAS. It should be mentioned that the comparative tests did not conducted on a specific building and the results can be taken as guidance of thermal simulation for any type of buildings.

3. An Overview of Using TAS and Ecotect for Thermal Simulation

Ecotect is a building design and environmental analysis tool that covers broad range of analysis functions including thermal and lighting simulation [5]. Ecotect is a highly visual building simulation tool which has been used by many researchers to evaluate the required design configurations in different types of buildings in various climatic regions.

- Utama and Gheewala in 2008 utilized the Ecotect to assess the influence of the enclosure materials on the energy consumed in single landed houses in Indonesia. The simulated results from ECOTECT were cross-checked with actual measurements and were found within 2–5% of the actual measurements [6].
- Utilizing the Ecotect, Kharrufa and Adil in 2008 defined the effect of the roof pond on temperature in buildings in hot arid climates [7].
- Utama and Gheewala in 2009 applied the Ecotect to examine the effect of the envelope materials on the energy consumed in high rise residential buildings [8].
- Ecotect was also used by some researchers for shading analysis [9].
- Sadafia, Salleha, Hawb , and Jaafar in 2011 utilized the Ecotect to examine the effects of introducing an internal courtyard on thermal comfort performance of a tropical terrace house [10].
- Oikonomou and Bougiatioti examined the environmental performance of the traditional buildings in Greece using Ecotect [11].

TAS is a software package for the thermal analysis of buildings which includes a 3D modeler, a thermal/energy analysis module, a systems simulator and a 2D CFD package. It is the most comprehensive thermal simulation tool of a building, and a powerful design tool in the optimization of a buildings environmental, energy and comfort performance [2]. TAS has been used by various researchers to assess thermal performance of buildings.

- Gorgolewski, Grindley , and Probert in 1996 in their research utilized the TAS to predict the effects of various improvement measures (thermal insulation, double glazing, ventilation control measures, and sunspaces) in the thermal performance of high-rise houses in the UK [12].
- TAS was used also by Tahata, Al-Hinaib, and Probertc in 2002 to asses several design options (the building's orientation, the building's form, the window-to-wall area ratio, and the amounts of thermal insulation) and their effects on the thermal performance of a residential building in Mediterranean climate [13].
- Panayi in his research in 2004 utilized the TAS in prioritising the energy investments in new dwellings (apartments and detached houses) constructed in Cyprus [14].
- Gratia and Herde utilized TAS in different studies to examine the thermal behaviours of double-skin facades in office buildings [15] [16] [17].
- TAS was also utilized by some researchers to estimate energy consumption, thermal comfort, and condensation of double glazed facade of a typical office building in Singapore [18].
- The CFD package of TAS was used by Macias in 2006 to apply and optimize night-ventilation strategies to social housing design in dry hot climate [19].
- Tenorio in 2007 applied TAS along with other simulation program
- s (ESP-r, and photovoltaic Design PRO-G) to assess the potential of the hybrid use of air conditioning in sustainable housing [20].
- Other researchers used TAS to investigate the potential savings in cooling energy of applying a rooftop garden for university buildings in the tropics [21].
- Liping and Hien in 2007 investigated the impacts of four different ventilation strategies on indoor thermal environment for naturally ventilated residential buildings located in hot humid climate [22].

However, few researchers conducted comparative analysis using multiple thermal analysis tools. Among those researchers;

- Marsh and Al-Oraier in 2005 carried out a comparative analysis between Ecotect and two thermal analysis tools (EnergyPlus and HTB2) [23]. The analysis considered seven parameters including Infiltration/Ventilation Rate, Internal Gains, Window Shading, Wall and Roof Reflectance, Wall and Roof Insulation, Orientation, and Evaporative Cooling. The parametric analysis does show noticeable variation between tools in their sensitivity to individual parameters. However, the overall shapes of the sensitivity curves were all very similar, with only differences in magnitude.
- Makaka and others used the Ecotect and DOE to simulate the thermal performance of low-cost passive solar houses in South Africa [24]. Ecotect and DOE simulation results show small differences in peak and minimum values.
- Crawley, Hand, Kummert, and Griffith contrasted the capabilities of twenty major building energy simulation programs (including TAS & Ecotect) in 14 categories [25]. However, the comparison was not based on running simulations and it was based on information provided by the program developers.

4. Input Data for the Comparative Tests

Various specific tests are conducted to investigate and compare how the two selected programs, Ecotect and TAS, consider thermal mass, ventilation, and solar gain. The quality of the results of the comparative tests depends on supplying the two programs with the same input data, particularly with regard to; climate, site, geometry, construction, ventilation, and internal gains. Therefore, the same weather file was used in both programs, which is for a Bayt Dajan weather station located in the coastal zone in Palestine at 32.0 ºN, 34.82 ºE. The weather file was transformed to electronic forms compatible with the two simulation programs; "twd" format for TAS and "wea" format for Ecotect. Internal gains are set to zero in all tests. The tests were carried out on two concrete cubes which have the same dimensions (9*9*9 meter); windowless cubes and cubes with south glazing facades -which are referred to as ***Gcubes***.

The major obstacle was providing both programs with the same properties for constructions. Description for opaque and transparent constructions used in the comparative tests is clarified below

4.1. Opaque Constructions

TAS and Ecotect are different in the required inputs for constructions, where some properties are required as input in one program while not required in the other. In TAS, the layer properties can be edited by the user, while the construction properties cannot be edited as they are calculated with the software itself according to the layer properties. In Ecotect, both the layer and the construction properties should be edited by the user. In comparative tests, concrete was used with the characteristics explained in (table 1). All the layer properties and some of the construction properties needed in Ecotect were obtained from TAS and edited in the data input interface of the Ecotect. Decrement factor, admittance, U-value, and time lag, which are required in Ecotect for the different building components, are calculated using "dynamic thermal property calculator V1.0" based on ISO13786.
Different thicknesses of concrete are used in the comparative tests including 100, 200, 300, 400, and 500 mm. Therefore, thermal properties for concrete with those thicknesses are also calculated. It is worth noting that the U-value given in TAS is displayed for information purposes only and not used in modeling calculations (TAS manual, 2010). Besides, the U-values, which are calculated using the electronic calculator, exactly match those provided in TAS.

4.2. Transparent Constructions

In some comparative tests, 6 mm single clear glazing material is also used for the south façade of the *Gcube*. The required parameters for the transparent materials in TAS and Ecotect are quite different. Table 2 provides the properties of glazing used in the comparative tests. As indicated in table 2, different expressions are displayed in both programs for the same term. For instance, the "G value" provided in TAS and the "Solar heat gain coefficient SHGC" provided in Ecotect are two expressions for one term; where the former is commonly used in Europe and the later is used in the United States.

Table 1 Properties of concrete used in comparative tests

Layer Properties			
Parameter		TAS	Ecotect
Width (mm)		100	*100*
Density (kg/m^3)		1800	*1800*
Conductivity (W/m.ºC)		1.13	*1.13*
Specific heat (J/kg. ºC)		1000	*1000*
Vapour diffusion factor		9999	....
Convection Coefficient		0.001	....
Solar Reflectance	External	0.3	....
	Internal	0.3	....
Light Reflectance	External	0	....
	Internal	0	....
Emissivity	External	0.9	....
	Internal	0.9	....

Construction Properties			
Parameter		TAS	Ecotect
Emissivity	External	0.9	*0.9*
	Internal	0.9	*0.9*
Solar Absorption	External	0.7	*0.7*
	Internal	0.7	
Visible Transmittance (0-1)		....	0
Specularity		....	0
Color [Reflect]		....	0.75
U-value (W/m^2.ºC)	Roof (Ext-Up.)	4.376	4.376
	Wall (Ext-Ho)	3.869	3.869
	Floor (Ext-Do.)	3.35	3.35
Admittance (W/	Roof	....	**5.37**
	Wall	....	**4.65**
	Gr floor	....	**3.93**
Decrement Factor	Roof	....	**0.89**
	Wall	....	**0.87**
	Gr floor	....	**0.85**
Time Lag (hrs)	Roof	....	**2.37**
	Wall	....	**2.52**
	Gr floor	....	**2.67**

Legend:
Normal :Data provided by the software itself
Italic :Date taken from TAS and edited in Ecotect
Bold :Data calculated using a calculator
Underline: Data calculated using a calculator and which match TAS calculation.

Table 2: Properties of glazing used in comparative tests

Layer properties				Construction properties		
Parameter		Ecotect	TAS	Parameter	Ecotect	TAS
Width (mm)		*6*	*6*	*U value (W/m^2.°C)*	*5.74*	*5.74*
Conductivity (W/m.°C)		*1.05*	*1.05*	*Visible/Light Transmittance (0-1)*	*0.881*	*0.881*
Density (kg/m^3)		2300	......	*G value/Solar heat gain coefficient SHGC*	*0.816*	*0.816*
Specific heat (J/kg. °C)		836.8	......	R value (m^2.°C /W)	....	0.174
Vapor diffusion factor		....	9999	Conductance (W/m^2.°C)	....	174.33
Convection Coefficient		....	0	Specularity	0	....
Solar Trans.		....	0.78	Color [Reflect]	0.737	....
Light Transmittance		....	0.88	Refractive index of glass	1.74	....
Solar Reflectance	External	....	0.07	Alt. Solar Gain (heavywt)	0.47	....
	Internal	....	0.07	Alt. Solar Gain (lightwt)	0.64	....
Light Reflectance	External	....	0.08	Admittance	6	....
	Internal	....	0.08	Legend:		
Emissivity	*External*	*0.84*	*0.84*	Normal: Data required in one program		
	Internal	*0.84*	*0.84*	*Italic : Data required in both programs (TAS & Ecotect)*		

The following sections discuss comparative tests conducted to investigate how Ecotect and TAS consider thermal mass, ventilation, and solar gain.

5. The Comparative Tests

Several comparative tests were conducted on the two selected computer programs (Ecotect and TAS) comprising comparative tests for; thermal mass, solar gain, and ventilation. The thermal mass comparative tests were conducted on concrete cubes with various thicknesses (comprising 100, 200, 300, 400, and 500 mm) and on both free running cubes (FR) and air conditioned cubes (AC). These tests investigated thermal mass of exposed components. The internal gains, the infiltration rates, and the ventilation are set to zero in all cubes. In air conditioned cubes, lower temperature is set 18 °C, upper temperature is set 25 °C, and humidity is set 60%. The results comprise outside and inside air temperatures, as well as fabric loss/gain. The solar gain comparative tests are intended to demonstrate how TAS and Ecotect consider the solar gain through glazing elements and its impact on the internal air temperature, and fabrics behavior. The effect of fabrics' properties such as internal solar absorption on solar gain was also examined on both programs. The tests were conducted on cubes have south glazing facades (*Gcubes*).The ventilation comparative tests are aimed to compare TAS with Ecotect in terms of considering the ventilation in predicting the internal air temperature, the ventilation load, and the fabrics loss/gain. Therefore, the tests were carried out on free running cubes with two thicknesses (10 and 30 cm) with various air change rates (0, 1, 10, 20, 30, and 40 acr). All tests were also conducted for both a summer and a winter days. The results from TAS and Ecotect are discussed and compared below.

6. Results and Discussion

6.1. Thermal Mass Comparative Tests

6.1.1. Inside Air Temperature of Free Running (FR) Cube with Various Thicknesses

The results show that, the internal air temperature estimated by TAS in a summer-day is always higher than that estimated by Ecotect in all cubes with a maximum discrepancy of 10.3 °C (see figure 2). The difference of the internal air temperature between the two programs increases with the increase of fabric thickness. In addition, according to Ecotect results, the internal air temperature for all cubes in a summer-day, excluding 10cm cube, ranges from 17.6 to 24.4 °C, which means no need for cooling. In contrast, all cubes require cooling in accordance with TAS results as the inside air temperature ranges from 22.3 to 34.8 °C. Although there is an observed significant difference between TAS and Ecotect results in terms of air temperature, the swings of temperature through the day are compatible in both programs for each thickness, where the swings dampen with higher thicknesses with the influence of thermal storage.

The results for winter are similar to those for summer in that the internal air temperature predicted by TAS is higher than that predicted by Ecotect. Therefore, all cubes require heating according to Ecotect simulation, while there is almost no need for heating according to TAS results since the estimated air temperature is generally higher than 18 °C.

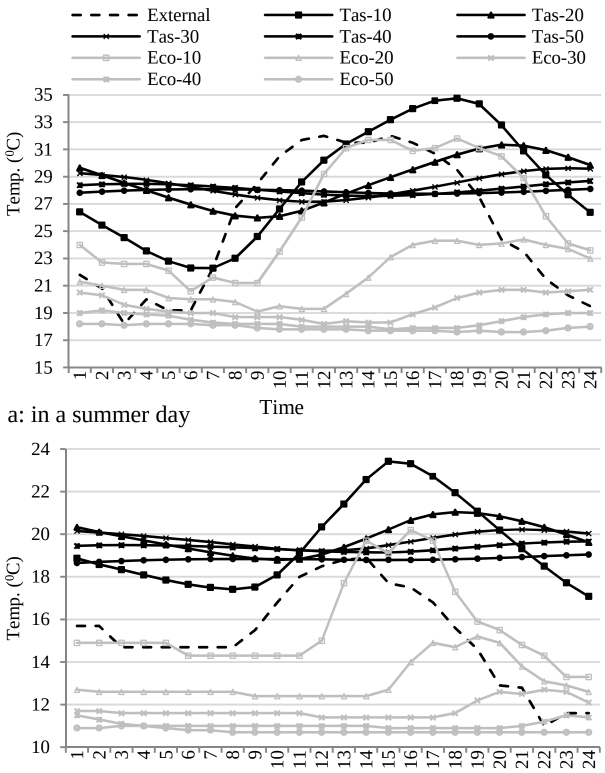

Fig 2 Temperature in free running (FR) cubes of various fabric thicknesses

6.1.2. Fabrics Gain/Loss of Free Running (FR) Cube with Various Thicknesses

Heat gain and loss through fabrics were also examined in TAS and Ecotect for all cubes, in a summer and a winter day (see figure 3). It was revealed a significant difference in fabrics loss/gain estimated by TAS and that estimated by Ecotect. For instance, the maximum fabric gain of 10 cm cube in summer is 500 watt according to TAS simulation, while it is 25000 watt according to Ecotect simulation. Besides, the results show that, in both summer and winter, the total fabric loss equals the total fabric gain as estimated by TAS, while they are not equal as estimated by Ecotect with no fabric loss in summer. It is noted that the peak fabric gains estimated by Ecotect takes place almost four and two hours later of that estimated by TAS in summer and winter respectively.

Although the discrepancy between TAS and Ecotect in predicting fabrics loss/gain, results from both programs indicate that with the increase of fabrics thickness, fabrics loss/gain decreases, and more delay of heat loss/gain takes place.

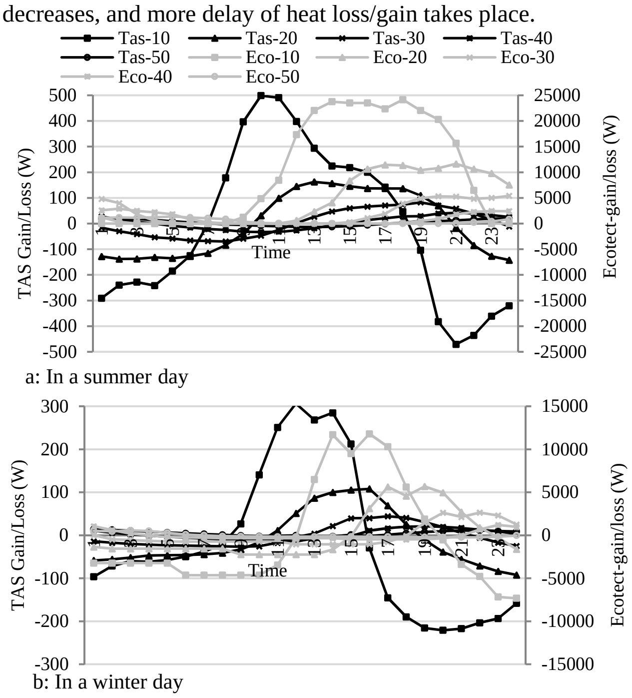

Fig 3 Fabric gain/loss for free-running (FR) cubes of various fabric thicknesses

6.1.3 Fabrics Gain/Loss of Air Conditioning (AC) Cube with Various Thicknesses

Fabrics loss/gain of air conditioned (AC) cubes of various thicknesses, in a winter and a summer days, is also examined (see figure 4). Results revealed that fabrics loss/gains of AC cubes are the same as those of FR cubes according to Ecotect results, in both summer and winter. However, heat flow through building fabrics is influenced with the internal air temperature. Therefore, Ecotect's prediction for the fabric loss/gain is reasonable only in summer results of 20, 30, 40, and 50 cm cubes, as the internal temperatures of these cubes in summer stay the same in the case of free running and air conditioning. However, for all cubes in winter and for 10 cm cube in summer, internal temperatures in these cubes in the case of air conditioning differ from those of free running. On the other hand, in TAS, fabrics loss/gain for air conditioned (AC) cubes is higher than that for free running (FR) cubes in the case of 10 cm cube in winter and in all cubes in summer. For the rest cubes in winter (20, 30, 40, and 50 cm cubes), fabrics loss/gain is unchanged because the internal air temperatures in these cubes fall between 18 and 25, i.e. do not change with air conditioning.

6.1.4. Ecotect- Fabrics Gain/Loss of FR Cube with Various Comfort Band

It was observed that, in Ecotect simulation, even for free running buildings, the lower and the upper comfort bands must be entered by the user into the zone settings interface. Therefore, the effect of various comfort bands on air temperature and fabric loss/gain is examined. The results revealed that the predicted internal air temperatures of free running cubes at various comfort bands are the same, while fabric loss/gain is influenced with the comfort bands. Lower fabric gain is associated with high comfort bands, and lower fabric loss is associated with low comfort bands. It is worth noting that comfort bands are required in Ecotect to be entered by the user for natural ventilation buildings too. However, the thermal performance of natural ventilation and free running buildings should not be influenced with the comfort bands. Therefore, it is not reasonable for Ecotect to involve comfort bands for buildings without heating or cooling system.

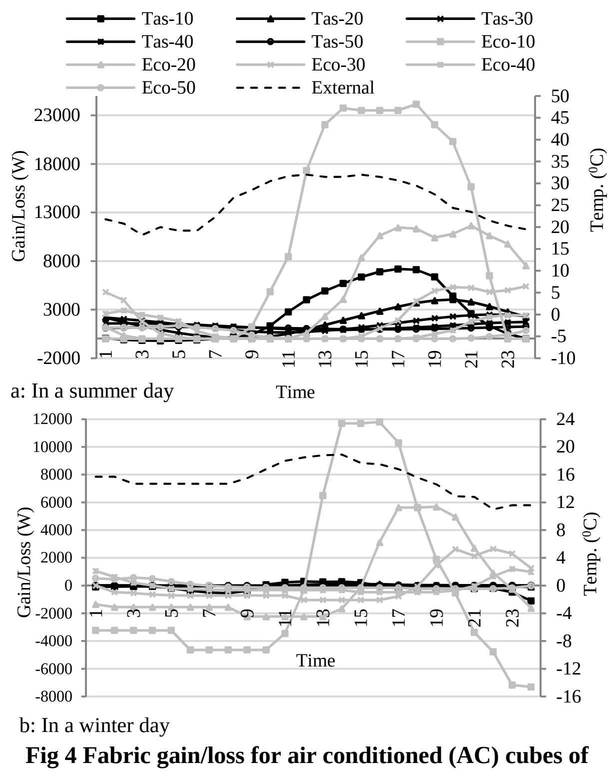

Fig 4 Fabric gain/loss for air conditioned (AC) cubes of various fabric thicknesses

6.2. Solar Gain Comparative Tests

6.2.1. Temperature in Cube with South Glazing Façade (Gcube)

According to both TAS and Ecotect simulations, the internal air temperatures in ***Gcubes*** in winter are overall higher and with greater swings than those in cubes, particularly with large thermal mass (see figure 5). However, discrepancy between ***Gcubes*** and cubes in terms of the internal air temperature in winter is greater in TAS modeling than in Ecotect modeling.
On the other hand, results from both TAS and Ecotect show that the internal air temperature of all ***Gcubes*** (10 and 30 cm) in summer is higher than that in all cubes during the daytime and

lower than it during the night. However, there is no difference between the average daily temperature in 10cm cubes and that in 10 cm ***Gcubes***, and the average daily temperature is slightly higher in 30 cm ***Gcubes*** than in 30cm cubes.

6.2.2. Fabrics Loss/Gain of Cube with South Glazing Façade (Gcube)

Fabrics loss/gain of ***Gcubes*** is examined in both programs; on free running ***Gcubes*** as well as on air conditioned ones. Results indicate a significant difference between TAS prediction and Ecotect prediction. In Ecotect modeling, like fabrics' behavior of cubes, fabrics loss/gain of free running ***Gcubes*** is the same as that of air conditioning ***Gcubes***, while in TAS they are different. It is worth noting that, in TAS simulation, in free running buildings, the total heat loss should equal the total heat gain. Thus, fabrics loss estimated by TAS is approximately equal solar gain through south glazing facade.

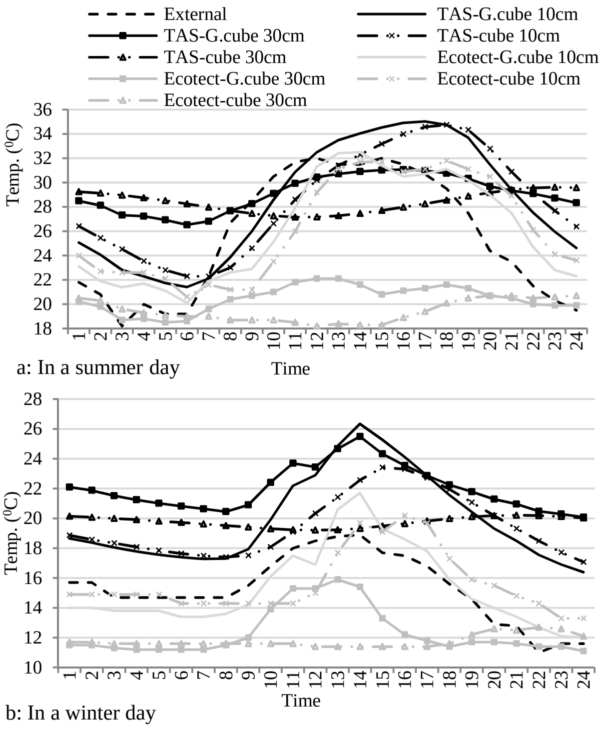

Fig 5 Temperature of free-running (FR) *Gcubes* (10&30 cm thickness)

6.2.3 Solar Gain of Cube with South Glazing Façade (Gcube)

The solar gains of AC and FR ***Gcubes*** which estimated by TAS for a winter and a summer days were compared with those estimated by Ecotect. It was found that solar gain in the case of air conditioning ***Gcubes*** is the same as that of free running ***Gcubes***. As shown in figure 6, in both programs solar gain in winter is greater than that in summer. Besides, results are similar in the times in which solar gains reach the peak and stop. However, results are dissimilar in the time of starting of solar gain, where it starts one hour later in Ecotect, in both summer and winter. Moreover, the magnitude of solar gain estimated by TAS is almost two times that estimated by Ecotect in both summer and winter. The difference in the results could be due to the limitation of the admittance methods on which Ecotect is based. Hensen and Radosevic in their research paper argued that, in admittance method, either the algorithm for solar gain calculation does not work properly or it was not implemented in the correct way [26].

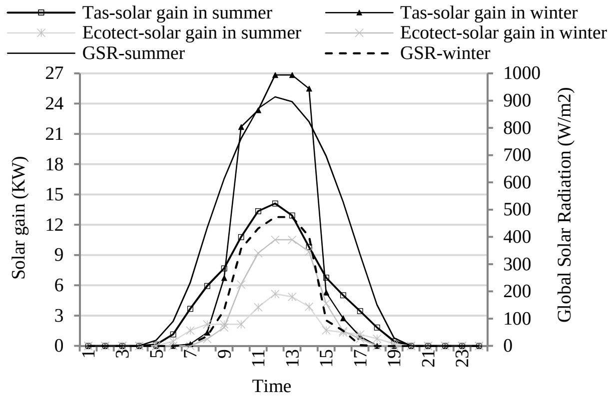

Fig 6 Solar gain of fee-running (FR) Gcube in a winter and a summer days

6.2.4 The Effect of Internal Solar Absorption on Solar Gain

This test conducted on free running 10 cm G.cubes of various internal solar absorption (0, 0.1, 0.3, 0.7, and 1), for both a summer and a winter days. The results revealed that Ecotect does not consider internal solar absorption in estimating solar gains, where solar gains stay constant with the various fabrics' solar absorption. This could be due to the limitation of admittance methods on which Ecotect is based ; as it is stated in Ecotect manual that; "*the method does not track solar radiation onto individual surfaces once it has entered a zone*".

On the other hand, according to TAS simulation, higher internal solar absorption of fabrics is associated with greater solar gain. It is also observed that; as the internal solar absorption rises, the magnitude of increasing in solar gain decreases. For instance, a discrepancy in solar gain in winter between two ***Gcubes*** with 0.0 and 0.1 internal solar absorption reaches a peak of 9.5 KW, while the maximum discrepancy between two ***Gcubes*** with 0.7 and 1.0 internal solar absorption is only 1.5 KW.

6.3. Ventilation Comparative Tests

6.3.1. The Effect of Various Air Change Rates on Ventilation Load

The ventilation loss/gain of the cubes (10 and 30 cm) was also demonstrated for various ventilation rates, for both a summer and a winter days (see figure 7). Some similarities and several differences between TAS and Ecotect in considering ventilation load were observed and limitations of Ecotect were discovered.

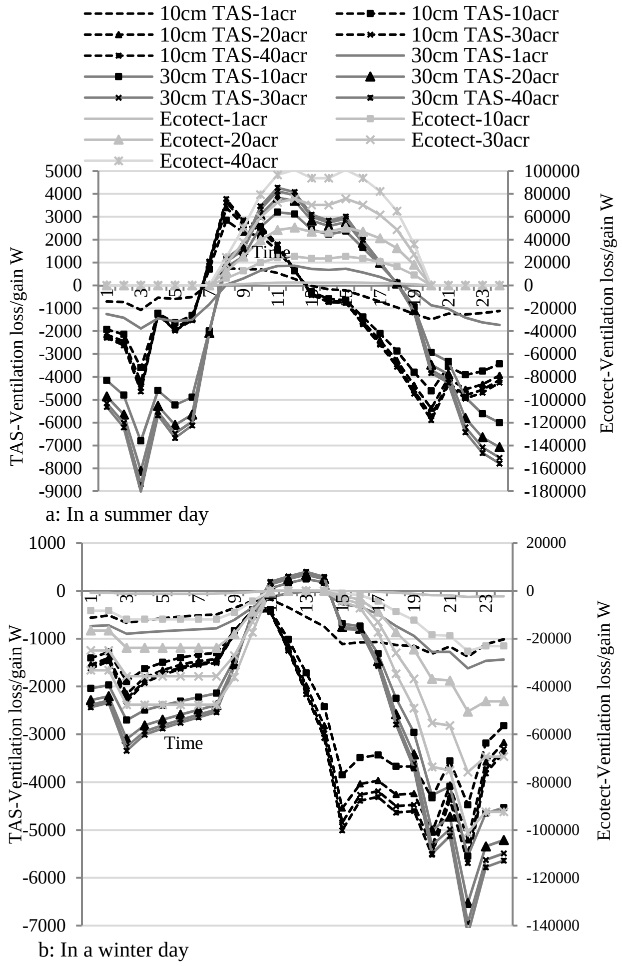

Fig 7 Ventilation loss/gain for free-running (FR) cubes (10 & 30 cm thickness) with various air change rate (acr)

First, fabrics thickness does not affect the ventilation load in Ecotect results, while in TAS, the ventilation loads of 10 cm cubes are different from those of 30 cm cubes for each ventilation rate. Second, higher ventilation rate is associated with greater ventilation load in both programs. However, in Ecotect, the ventilation load rises steadily with the increase of the ventilation rate, while in TAS, the magnitude of increase in the ventilation load fades significantly with higher ventilation rate. Third, the ventilation loss in Ecotect in winter is extremely higher than that in TAS, and the ventilation gain in Ecotect in summer is extremely higher than that in TAS (see figure 7), where different Y-axis scales are used for TAS and Ecotect results). Fourth, in Ecotect, although the internal temperature estimated by the program is almost higher than the external temperature, particularly 30 cm cubes, only ventilation loss takes place

6.3.2. The Effect of Various Air Change Rates on Fabrics Gain/Loss

These tests were intended to demonstrate the impact of the ventilation on predicting the fabrics loss/gain by TAS and Ecotect. The tests revealed that Ecotect does not consider the ventilation in predicting the fabrics behavior, where the fabrics loss/gain was found to be constant for various air change rates. Conversely, in TAS, the fabrics loss/gain decreases with the increase of ventilation rate.

7. Conclusion

After running the comparative tests, a clear picture about the capabilities of TAS and Ecotect is gained. The discrepancies between the programs' simulations were revealed and the limitations were discovered. The internal air temperature predicted by TAS is higher than that of Ecotect particularly with large thermal mass. There is a significant difference in the fabrics loss/gain estimated by TAS and that estimated by Ecotect. The magnitude of solar gain estimated by TAS is almost two times that estimated by Ecotect. The ventilation load according to Ecotect rises steadily with the increase of the ventilation rate, while in TAS; the magnitude of increase in the ventilation load fades significantly with higher ventilation rate. Further, the ventilation load estimated by Ecotect is extremely higher than that estimated by TAS.

Further, it was revealed some limitations in Ecotect. First, fabrics loss/gain for AC & FR building is the same. Second, air change rate does not affect fabrics loss/gain. Third, comfort bands are required for FR & NV buildings, and affect fabrics loss/gain. Fourth, direct solar gain is not influenced with fabrics thickness. Fifth, internal solar absorption is not considered in estimating solar gain.

TAS is more comprehensive in predicting the thermal behavior of the fabrics as it could estimate the heat loss/gain for each component in the building separately. Besides, TAS is based on a calculation method (A method derived from response factor technique) which is more accurate than that of Ecotect (the Admittance method). Some of the Ecotect's limitations, which are revealed by the comparative tests, could be related to the admittance method which the program is based on. Further, TAS database (especially the construction database) is richer than that in Ecotect, and TAS user manual includes video tutorial making learning procedures easier. On the other hand, input process in TAS is more complex and more time consuming than in Ecotect.

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