

Assessment of Occupants' Thermal Condition and the Risk of Overheating in Sustainable Public Libraries in Auckland Region

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Abstract:

This paper examines the thermal condition of occupants and the risk of overheating in two award winning sustainable public libraries in Auckland region of New Zealand through long term environmental monitoring of the building performance and occupants' survey. The survey was performed on eight staff of the library who have occupied the buildings for more than two years. The data were further contrasted with the risk of overheating assessment which were based on thermal comfort design parameters for free-running buildings. The standards that define the risk of overheating used in this study are CIBSE A 2006 standard the British Standard EN 1525; the TM52 CIBSE; and Building Bulletin 101 (BB101). The results demonstrate that none of the libraries are at the risk of overheating during the summer season. However, the building occupants claimed that in certain periods, the buildings can get overheated, even though, adaptive comfort criteria was used to design these libraries. The discrepancies between the overheating risk methods and the surveys can be further explained by the fact that none of the overheating methods considered the effects of the water content in the air. Such parameter is proven to have an effect on the capacity of the body to reduce its own temperature through the evaporative effect in the skin. Therefore, a standard that takes into account the humidity ratio such as the ASHRAE 55 might shed light to understand the thermal comfort responses of the occupants. The study provides insight into the socio-technical issues in overheating risk assessment in the context of public libraries in temperate climates.

Keywords: Sustainable building, overheating, thermal comfort condition, public library

1. Introduction

Overheating in buildings has historically been quantified by the number of occupied hours per year that the indoor operative temperature exceeds a particular threshold. However, this methodology disregard the effects of the external air temperature, which according to de Dear and Brager [1] can greatly influence the thermal sensation of the occupants because of the ability of people to adapt to changing conditions [2 and 3]. Therefore, occupants are more

comfortable with higher indoor operative temperature during prolonged warm weather (summer season).

[4] provides a comprehensive set of recommendations regarding the overheating risk in free-running buildings. Depending of the type of building, the standard states a maximum amount of occupied hours above a certain threshold. In the case of offices and schools areas, the criterion indicates that a maximum of 1% of the annual occupied hours can exceed an operative temperature of 28°C. CIBSE Guide A uses a static range of acceptable comfortable temperatures based on the principle that people are more tolerant to higher temperature during warm seasons.

On the other hand, the Building Bulletin 101 issued by the Education Funding Agency specifies ventilation performance for the design of school areas. Under its recommendations, the overheating risk can be assessed under three different criteria and requires at least two of them in order to consider the assessed space as not overheated.

- There should be a maximum of 120 hours when the operative temperature is above 28°C
- The indoor operative temperature should be less than 5°C above the external air temperature on average.
- The indoor operative temperature should never exceed 32°C when the space is occupied.

In a recent study [5] the above fixed thresholds were compared to the overheating criteria based on the adaptive thermal comfort principle [6], another relevant criteria to assess the overheating risk in libraries is the one proposed by the Passive House Planning Package. Although is mostly used to assess the overheating risk in houses, this method can be adjusted to different types of buildings by changing the threshold temperature. The method uses the frequency of occupied hours when the operative temperature exceeds an established comfort limit. The default maximum operative temperature is 25°C, however different temperature may be used for comparison.

This method threshold indicates that when the frequency of the operative temperature exceeding 10% of the annual occupied hours, additional heat protection measures would be necessary.

The most recent advancement in the study of overheating risk is the Technical Memorandum 52 (TM52), which is an extensive section within the latest CIBSE Guide-A [7]. The TM52 methodology is based on the comparison of the indoor operative temperature and the external running mean temperature. The external running mean temperature is calculated in a way that it places a greater importance to the external air temperature of the preceding days since they have more influence on people's comfort levels. This ultimately means that the upper comfortable limit will vary in function of the external air temperature in a dynamic way. In order to pass this requirement, two of the three following criteria must be met.

- The threshold temperature should not exceed by more than 3% of the occupied hours
- Daily weighted exceedance (degree hours) should not exceed six degree hours.
- The operative temperature should never exceed the upper temperature limit.

Finally, the method described in the BS EN 15251 [8] for free running buildings uses a method based on the adaptive algorithm of the European study SCATs. The algorithm was created based on a field study performed in Greece, Portugal, the United Kingdom, France and Sweden with the aim of developing a method that takes into account the ability of people to adapt to the changing conditions of their surroundings in order to improve thermal comfort and reduce the energy consumption of air conditioners.

Given this considerations, the aim of the present study is to assess the risk of overheating from the three libraries located in Auckland during the summer season. For this purpose, three different assessment criteria will be used considering the building type and its applicability

with the available tools. Furthermore, the results of the assessment were contrasted with interviews performed to occupants of the libraries. This provides an insight towards whether it is necessary to adjust the thermal comfort thresholds for buildings designed as libraries in New Zealand.

2. Methodology

In order to estimate the thermal performance of the free-running libraries, a survey was performed to some of the staff that work in the buildings to assess their thermal perception of the buildings. This information was further contrasted with a risk of overheating assessment, which are based on thermal comfort design parameters for free-running buildings. The most used and relevant standards that defines the risk of overheating used in this study where: (a) CIBSE A 2006 standard [4], (b) the British Standard EN 15251 [8], (c) the TM52 CIBSE [7] and (d) Building Bulletin 101 (BB101) [9]. Although, all these standards could assess if a building would reach a critic temperature, they oversee the effect of the water content in the air (humidity ratio), which can greatly influence the thermal sensation of a person and ultimately their response to the thermal environment as being too warm when the relative humidity is also high. Under this consideration, an extra assessment was carried in the present study to take into account the effect of the relative humidity in the temperature thresholds that a person could bear. The standard for such assessment was the (e) ASHRAE 55-2004 graphic method [10]. While this standard is not generally used to evaluate the risk of overheating of a building, it could correlate to the results of the survey since it considers the effect of the relative humidity. The Table 1 shows a summary of the different requirements stated by each standard.

Table 1. Summary of the assessment criteria to be used in this study

Method	Source
<ol style="list-style-type: none"> Percentage of occupied hours when $T_{op} > 25\text{ }^{\circ}\text{C}$ should be less than 5% Percentage of occupied hours when $T_{op} > 28\text{ }^{\circ}\text{C}$ should be less than 1% 	CIBSE Guide A, 2006
<ol style="list-style-type: none"> Threshold temperature (T_{max}) should not be exceeded by more than 3% of occupied hours. Daily weighted exceedance (degree hours) should not exceed 6 degree hours. T_{op} should not exceed the upper temperature limit (T_{upp}). 	TM 52 CIBSE, 2013
<p>Overheating risks occur when T_{op} is out adaptive temperature threshold range.</p> $T_{max}=0.33 T_{rm}+21.3$ $T_{min}=0.33T_{rm}-21.3$	BS EN 15251, 2007
<ol style="list-style-type: none"> Less than 120 hours when occupied hours are $T_{op} > 28\text{ }^{\circ}\text{C}$ $\Delta\bar{T}=\bar{T}_{op}-\bar{T}_{rm}\leq 5\text{ [K]}$ The operative temperature should never exceed $32\text{ }^{\circ}\text{C}$ 	Building Bulletin 101
T_{op} out of the temperature and relative humidity thresholds	ASHRAE 55 2004

3. Overview of the two field study cases

The two libraries located in three different locations in Auckland region of New Zealand were mainly designed considering sustainability parameters. One of the main sustainable measures is the use of natural ventilation, which combined with shading strategies and autonomous window control, are the main conditioning strategy during the summer season. The two libraries are located in Devonport north east of Auckland and Waiheke Island, east of

Auckland. The libraries are located in Devonport and Waiheke. Since the two locations are close to Auckland, the meteorological data from this city was used. Therefore, an hourly weather data file was generated from the nearest meteorological station located at North Shore Albany, which is managed by the National Institute of Water and Atmospheric Research (NIWA). This file was generated with data for the non-heating season which in New Zealand is from December (2017) to February (2018) Figure 1). A summary of the buildings' specifications is shown in Table 2.

Table 2. Summary of building specifications

Building	Devonport	Waiheke
Business type	Public library	Public library
Building area [m ²]	217	800
Type of window	Double glazing	Double glazing
Windows operation	Automated	Automatic and manual
Conditioning measure	Natural ventilation	Natural ventilation and heat pump
Number of people interviewed	3	5
Period of interview	December - February	December – February
Number of data loggers	4	4

4. Results and discussion

According to the standards CIBSE guide A, BS EN 15251, TM 52 and BB101, the three libraries have low chance of being overheated during the summer season in New Zealand (Table 3). However, all these standards neglect the proved effect of the moist in the air in the thermal sensation of people. This effect can explain why for some people, the buildings were either slightly warm or too warm. Therefore, a standard that take into account the effects of the relative humidity in the thermal sensation might help to further understand the actual thermal sensation of the occupants.

In Devonport, although none of the overheating assessment methods showed an actual risk of overheating, all the people declared that the environment is “hot” in the PMV scale. Therefore, when considering the relative humidity according to the standard ASHRAE 55 (Figure 1), in average 11.7% of the occupied hours are above the thermal comfort threshold. Although, this figure is not high enough to declare the building as overheated, it can further explain the people responses. Furthermore, it would be important to contrast the actual time when the survey was performed with the correspondent temperature and relative humidity in order to see if the interview was performed in a period when the temperature was above the maximum threshold. On the other hand, it has to be mentioned that there are a considerable number of hours with temperature lower than the minimum temperature threshold (in average 16.5%), but none of the surveyed people felt the environment as “cold” or “slightly cold”. Therefore, the time and hour of the surveyed would give clearer picture of the actual thermal performance of the building. Unfortunately, the time and date of the surveys are not available

Table 3. Summary of the results for overheating assessment

	Criteria		Devonport	Waiheke
CIBSE Guide A - 2006	Occupied hours $T_{op} > 25^{\circ}\text{C}$	< 5 [%]	28.10	17.97
	Occupied hours $T_{op} > 28^{\circ}\text{C}$	< 1 [%]	0.25	0.11
	Overheating		No	No
BS EN 15251- Category II	Occupied hours for heating	< 20 [%]	8.52	18.87
	Occupied hours for cooling	< 20 [%]	0.04	0.04
	Occupied hours in comfort	> 80 [%]	91.49	81.10
	Overheating		No	No
TM 52 CIBSE	He [%]	< 3 [%]	0.00	0.00
	We_{max}	< 6	0.00	0.00
	ΔT_{max}	≤ 4	0.00	0.00
	Overheating		No	No
BB101 (2006) criteria	Occupied hours $T_{op} > 28^{\circ}\text{C}$	< 120 [hours]	1.75	0.75
	$\Delta \bar{T} = \bar{T}_{op} - \bar{T}_{rm}$	< 5 [$^{\circ}\text{C}$]	3.53	3.01
	Occupied hours $T_{op} > 32^{\circ}\text{C}$	0	0.00	0.00
	Overheating		No	No
ASHRAE 55 (2004)	Occupied hours $T_{op} < T_{min}$	[%]	16.92	32.32
	Occupied hours $T_{op} > T_{max}$	[%]	11.83	8.84
	Overheating		No	No

In Devonport, although none of the overheating assessment methods showed an actual risk of overheating, all the people declared that the environment is “hot” in the PMV scale. Therefore, when considering the relative humidity according to the standard ASHRAE 55 (Figure 1), in average 11.7% of the occupied hours are above the thermal comfort threshold. Although, this figure is not high enough to declare the building as overheated, it can further explain the people responses. Furthermore, it would be important to contrast the actual time when the survey was performed with the correspondent temperature and relative humidity in order to see if the interview was performed in a period when the temperature was above the maximum threshold. On the other hand, it has to be mentioned that there are a considerable number of hours with temperature lower than the minimum temperature threshold (in average 16.5%), but none of the surveyed people felt the environment as “cold” or “slightly cold”. Therefore, the time and hour of the surveyed would give clearer picture of the actual thermal performance of the building. Unfortunately, the time and date of the surveys are not available.

The Devonport library showed a low change of overheating risk, even though the surveys revealed otherwise. The scattered nature of the answers demand a deeper assessment. Only 60% of the occupants found the library as “slightly warm” which is within an acceptable range. However, the fact that two people declared totally opposed thermal sensation struck as a surprise. Therefore, a closer look to the actual temperature and relative humidity according to the ASHRAE 55 standard might shed light to understand the answers (Figure 1). On the one hand, there is one answer that claim the indoor environment is “too warm”, which could be caused by two high temperature peaks during the assessment period, providing that the survey was performed in this particular time. Contrariwise, there is an answer that claims the environment is “too cold” which could have occurred if the survey was performed in one of the cold temperature valleys during the assessment period. However, that information is not available.

Finally, the Waiheke library showed a similar behavior since none of the overheating assessment resulted in overheating risk for this library. However, all the surveyed people declared the library as being “slightly warm” in the PMV scale. In this case, the results of the survey are aligned with the numerical calculation of the ASHRAE 55 standard since in average, only 8% of the occupied hours are above the upper temperature threshold (Figure 1). In fact, there are a considerable number of hours below the minimum temperature threshold (i.e. in average 32%). However, none of the surveyed individuals declared that the environment was cold. These results, opposed the adaptive assumption that claim that people prefer warmer temperatures during summer or extended periods of warm weather since apparently, the respondents would prefer a slightly colder temperature. However, this uncertainty in the results would be solved by knowing the exact time and date of the survey in order to contrast it with its corresponding temperature and relative humidity.

Therefore, a new approach regarding the survey might be necessary such as in-depth interviews where people might openly share their understanding of the environment and how this affect their surroundings and daily work.

5. Conclusions and recommendations

Overheating risk assessment was performed in two libraries that share the weather conditions of Auckland in New Zealand. The assessment was further contrasted with surveys and a thermal comfort analysis following the graphical method of the ASHRAE 55.

The results obtained with the overheating assessment demonstrated that none of the libraries are in risk of getting overheated during the summer season in New Zealand which is from December to February. However, the users of the building claimed that in certain periods, the buildings can get overheated, even though, adaptive comfort criteria were used to design these libraries.

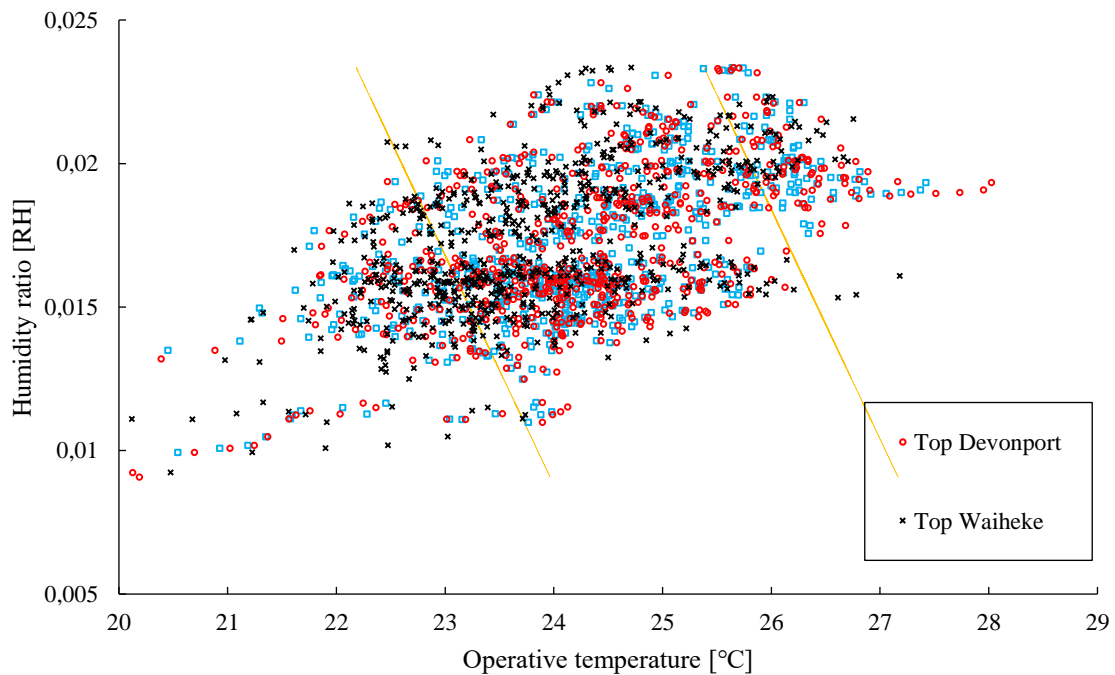


Figure 1. ASHRAE 55 graphical method

The discrepancies between the overheating risk methods and the surveys can be further explained by the fact that none of the overheating methods consider the effects of the water content in the air. Such parameter is proven to have an effect on the capacity of the body to reduce its own temperature through the evaporative effect in the skin. Therefore, a standard that takes into account the humidity ratio such as the ASHRAE 55 might shed light to understand the thermal comfort responses of the occupants.

In this regard, when the humidity ratio is considered, the thermal comfort thresholds are reduced and the number of hours that might be considered as uncomfortable rose in each case. Even so for the lower temperature limit, which was also reduced increasing the amount of hours where the temperature is colder than the comfortable threshold. However, only one of the surveyed subjects claimed that the environment was “too cold”. Unfortunately, the time and date when the surveys were performed is missing, precluding the ability of further contrast between the survey time and its corresponding temperature and relative humidity.

Furthermore, people using this kind of buildings would miss the opportunity to adapt to its thermal conditions. Therefore, their experience might differ from people working in these environments and that are already adapted. On the other hand, commonly used methods might not be the most appropriate tool for this kind of buildings since they are based on the adaptive assumption that occupants will adapt their behavior according to previous experiences. But if they only use the building scarcely, a different approach might be necessary. In this regard, in-depth interviews might shed light on how people who is not adapted to the building finds thermal sensation of the built environment.

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