Monitoring of Miele corporate headquarters Johannesburg, South Africa

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ABSTRACT: This paper describes the setting up of a monitoring program to identify and quantify the most significant problems relating to occupant discomfort encountered in a commercial building in Johannesburg, South Africa. It discusses the rationale behind the program and describes some of the problems encountered.

The building is the South African corporate headquarters of the international Miele group completed approximately two years ago. The building consists of three distinct zones, these being firstly the administration offices, secondly a showroom and thirdly a workshop and spares store.
The building was conceived as a passively cooled and ventilated building. However, due to various changes and modifications during the design development and construction the client's expectations have not been met in terms of thermal comfort.

The saw tooth roof configuration was used by the designer to ventilate and cool the deep spaces of the showroom and workshop areas by means of the stack effect. Data collected over a long period illustrates that this strategy functions only under certain conditions. The paper speculates as to the interpretation of the data obtained.

Keywords: Monitoring, thermal comfort, passive design, data logging, micro-climate

1 INTRODUCTION

The new South African corporate headquarters of the international Miele group completed approximately two years ago, is a project in which the conceptual design was performed by one architect and then handed over to another firm of project architects for detail design, documentation and supervision during construction. At the client's insistence, a developer was appointed and an overall cost cap was placed on the project. Whilst being outside the limitations (scope) of this paper it is important to note that many of the design details which may have enhanced the thermal performance of the building were sacrificed (or simply left out) to save on costs. It is, however, debatable whether the building, as conceived and designed, would have in fact offered the desired thermal comfort. Again, it is beyond the scope of this paper, but it is the intention as part of a more encompassing case study to conduct a computer based thermal modelling exercise wherein some of the design parameters will be changed in order to gauge the effect of the changes made to the building during construction.

Figure 1: Miele building from South South West.

2 OBJECTIVES

The primary objective was to use this case study as an academic and research project to give students and staff a better understanding of how one may evaluate the actual performance of a building of this nature, post occupancy, and its contribution to low energy architecture. A secondary objective was to help advise the client as to possible interventions to improve thermal comfort levels. The client did not appoint the university nor help finance the study in any way but made the building available in their own interest in what they saw as a low energy and "green" building.

3 CLIMATIC CONDITIONS

3.1 The city of Johannesburg lies within the so-called Highveld climatic zone (Holm, 1996: 64). The average summer and winter temperatures are 21,1°C and 10,17°C respectively with an RH of 56%. The average monthly rainfall is 59mm and annual rainfall is 714mm. Most of the rainfall, 349mm or 49% falls during the months November – January (summer in the southern hemisphere).

3.2 Microclimate

As can be seen from the photographs fig 2 and 3, the building lies in a valley and its thermal behaviour is probably influenced by the microclimate. There are high trees to the north of the site. Due to the slope of the ground, buildings to the west of the site are higher than the Miele building and may also influence the microclimate. In order to obtain exterior climate data it was decided to install a weather station on the site to obtain site conditions over an extended period of time.

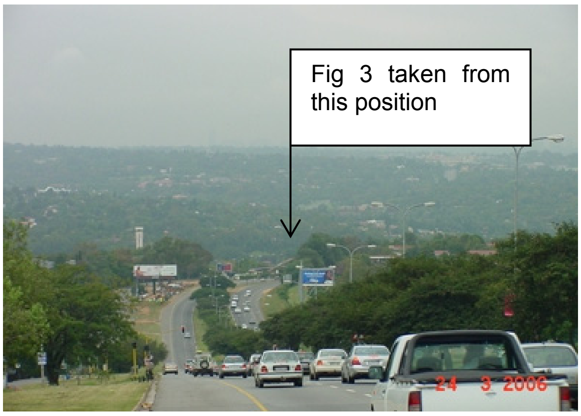

Figure 2: Photo showing the valley in which the building is situated

Figure 3: Photo showing how, the valley in which the building is situated, flattens out

4 THE BUILDING CONCEPT

4.1 The building consists of three different functional areas. The showroom is the most important feature and is a double volume, column free space. The offices and administrative services are located in a double storey structure which overlooks the showroom. The spares store and workshop is attached to the showroom and separated by a wall which has limited connection with the showroom by means of doors. See figures 4 and 5.

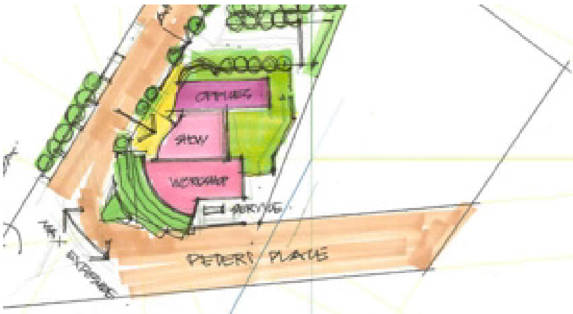

Figure 4: Conceptual drawing showing basic layout

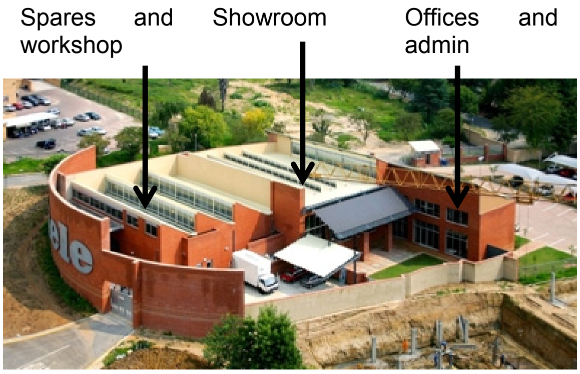

Figure 5: Aerial view showing the three functional zones

4.2 The building was conceived as a “passively cooled and ventilated” building. Whilst these terms are freely used by architects and designers they have different meanings to different people. In this case there seems to have been an acceptance that the ventilation would occur as shown by the diagrams illustrated in figures 6 and 7. No engineer nor ventilation specialist was employed to check or verify that the desired ventilation rates needed to cool the building would be achievable.

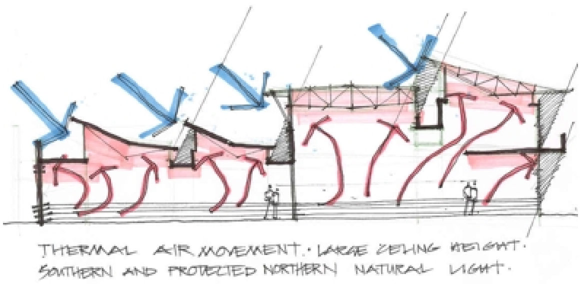

Figure 6: Conceptual drawing showing cooling

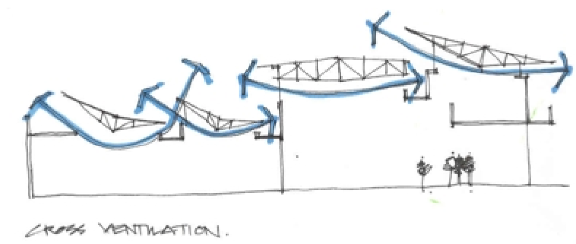

Figure 7: Conceptual drawing cross ventilation

The saw tooth roof configuration was used by the designer to ventilate and cool the deep spaces of the showroom and workshop areas by means of the stack effect.

4.3 In his design presentation to his client the designer refers to “very thick western and eastern walls for heat storage and extremely well insulated roof construction”. This statement indicates that he had some notion of using thermal mass to bring out a temperature damping effect.

4.5 Certainly the final result is very pleasing in terms of architectural aesthetics, and presents the client with beautiful spaces in which to display their products. There are very good levels of natural light (despite this, artificial lighting is so configured so that most lights are on during the day) and the building is well detailed and finished.

5 CHANGES MADE POST CONCEPTUAL DESIGN

The most significant changes made during the technical documentation and construction phases were as follows:

- Aluminium solar shading louvres were removed from north (equatorial facing) windows allowing deeper than conceived sun penetration.
- Ventilation openings at low level were removed thus removing natural air circulation.
- All adjustable louvre openings were changed to a fixed blade configuration resulting in the inability to have different settings for seasonal changes.
- 80mm thick EPS insulation in roofs was changed to 50mm thick EPS (75mm EPS is a commercially available product).
- The roof over the office area was to have been a ventilated void. The inlet louvre grilles under the eaves were removed but the outlet grilles were retained. This appears as an incongruous feature.
- Much of the landscaping, in the form of relatively dense planting of trees and shrubs was changed to small shrubs and grass. Possibly some of the ameliorating effects of air passing through vegetation have been lost.

6 THERMAL COMFORT

It is anticipated that some complaints are rooted in the expectation that air-conditioning is simply expected in a building of this nature. As staff feel that they have no control over their thermal comfort other than by opening or closing a window they will be unhappy and complain. Whilst there are justified complaints from staff that acceptable levels have not been met, the number of days when thermal comfort levels are not met are limited. During the summer months temperatures of 28-29°C with an RH of 23 - 26% (11 Feb 2005) were recorded in the offices of the General Manager and the Financial Manager. These conditions were accompanied by negligible air movement thus making the conditions uncomfortable.

7 MONITORING

Monitoring was based on two objectives. The first was to attempt to establish trends in the thermal behaviour of the building and the second was to establish absolute values in order to evaluate complaints from staff.

7.1 Monitoring had to done in such a way as not to impose on the functions of staff nor detract from the spaces in which the Miele appliances are exhibited or from the building itself. As part of an underlying strategy a decision was made to monitor multiple points to check the degree of correlation and further investigate any anomalies that may be evident.

7.2 In the office areas use was made of self contained loggers mounted at approximately 1700 high. These were simply attached to mullions of the partitions between offices using double sided adhesive tape. Three offices, on both the ground and first floor were selected. Two of the offices selected, were situated at the extreme ends of the building and one approximately in the middle. On the first floor, the middle location was actually the staff kitchen which was walled on only three sides and opened out onto the passage. Of all the locations, only this kitchen had very good cross ventilation.

Figure 7: Monitor on mullion

7.3 The showroom, stores and workshop were monitored in the form a grid pattern both on plan and in section. The thermometers were placed at the same horizontal levels and suspended from the trusses above. As there are no columns in the showroom, this presented the problem of suspending a cable with thermometers attached in space. The thermometers / thermocouples were mounted on chains, which were made up on the ground to ensure accurate fixing of the thermometers, so that when suspended form the trusses above they all hung at the same height.

The thermocouples were placed at three different positions on each chain. The positions were:

- 300 from the floor
- 3600 from the floor

In the middle of the fixed louvre grille above the windows

Figure 8: Making up of chains and monitor on chain

Figure 9: Chains suspended from underside of truss and showing positions of thermometers

It was not possible to hang chains in certain positions either due to them causing a major disruption to the client or due to unsafe working conditions. In such cases the wiring and thermometers were fixed to PVC electrical conduits which were fixed to columns.
In the workshops' and stores' areas, Miele management had no problem with the wiring simply being fixed to the steel columns as these are not areas open to the public. The same philosophy of positioning was followed.

7.4 Selecting a suitable position for the weather station proved to be problematic. Due to the long and narrow site, all locations to the South, East and West of the building would have meant that the weather station would have been in a protected position and readings would not have reflected the general microclimate. Of particular importance was the need to place the anemometer at a height suitable to measure the possible wind effects on the thermal behaviour of the building. The anemometer is connected to the base station by means of a 12 metre cable This means that is was not possible to mount the anemometer at roof height and still get the base station far enough from the building to negate the influence of the building. After much thought and discussion it was decided to mount the weather station to the North of the building as this had the following advantages;

- The height of the anemometer represents an average height of the louvre openings in the North façade of the building
- According to the wind rose of the Johannesburg area (macroclimate) the most prevalent wind direction is from the North.
- The vegetation and buildings on the Northern and western side of the building would have a significant effect on the microclimate.
- The position would allow the temperature gain over the paving to be determined

Figure 10 shows the weather station as viewed from a first floor balcony.

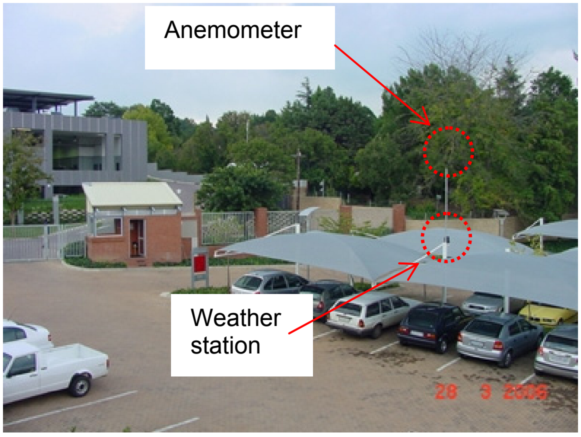

Figure 10: Weather station as viewed from a first floor balcony

7.5 Four points on the Northern façade were chosen for monitoring to determine inlet air temperature. Again the philosophy of determining the degree of correlation determined that four points be chosen.

Figure 11: Northern façade of building showing the monitoring points

8 EQUIPMENT USED

Financial constraints led to the purchase of some items of equipment that were less than optimal for the task expected from them.

8.1 The self contained loggers were HOBO H8 (8 bit family of loggers) manufactured by Onset Corporation of which 7 2-channel (temp and RH) and 3 single channel (temp) were used. The advantage of these loggers is that they are battery operated and have no wires attached. The sensors are mounted internally and the casings have vents which allow the ambient air to come into contact with the sensors. These have a good GUI and the software is easy to use.

8.2 A Davis Vantage Pro-2 was purchased for this purpose. This instrument is rather more suited to agricultural and hobby type applications than meteorological measurement but it represented good value for money. It comes supplied with good software and is particularly user friendly.

8.3 Several locally manufactured multi-channel data acquisition systems which use both analogue and digital bus based data logging capabilities were used. The system makes use of Dallas Semiconductor 1 wire digital thermometers (DS18B20 programmable resolution 1wire digital thermometers). Each thermometer has a unique 64bit serial code which allows multiple thermometers to function on the same bus. The A400 data acquisition system allows 16 of these thermometers to be coupled to the same bus.

9 CALIBRATION

None of the equipment used was calibrated and the manufacturer's specification both in terms of resolution and accuracy were accepted. This decision was made to save on costs. For example, calibration of the HOBO loggers cost about the same as the cost of the logger itself.

The Davis vantage Pro 2 carries the USA National Institute of Standards and Technology (NIST) certification.

The same vendor supplied both the weather station and the HOBO loggers and previous calibration exercises conducted on these makes of equipment indicated they were in specification.

The Dallas Semiconductor 1 wire digital thermometers are widely use in South Africa and again were generally found to be within their specification.

10 PROBLEMS ENCOUNTERED

Conducting a case study of this nature, in a city other than the one in which in one lives and works, proved to be difficult

10.1 The Onset HOBO H8 data loggers functioned well and the only problems encountered were that the double sided adhesive tape failed and the loggers fell from their mounted positions. They were picked up by staff and simply placed in any position for e.g. on the balustrade wall in the baking sun and rain. Some data was corrupted by this.

10.2 Even careful and precise following of the manufacturer's instructions proved to be insufficient in the case of the assembly of the anemometer. Despite assembly of the anemometer wind cups, with the correct amount of shaft end float (play) beneath the de-icing ring, the unit did not function. Only after having mounted the anemometer on a 6 metre pole and taking it down several times did it appear that there needed to be zero end float on the shaft. This was necessary as the magnet that is mounted in the anemometer triggers a small reed switch in the housing which is not very powerful. 0,5 mm seemed to make the difference!!

10.3 The greatest problems, however, came from the setting up of the digital one-wire bus system,

Despite the vendor being taken to site and the proposed layout of the thermometers discussed in detail, the system failed to function even although being installed as instructed by the vendor. Only after some considerable investigation it emerged, that these one wire bus systems are sensitive to both layout configuration and type of cabling used. In this particular case the cabling (that was in fact supplied to us by the vendor) had too high a capacitance. The cable was a screened UTP (untwisted pair) with a Mylar sheath.

The second problem was related to the configuration of the layout. According to the Dallas Semiconductor website, one wire bus systems function optimally when the thermometers are connected to it in a fishbone configuration. Star configurations are also not recommended as these generate electronic timing problems. The system as installed in the Miele building was possibly a worst case scenario being a hybrid star layout with each leg of the star being a fishbone layout. Even the vendor was unaware of these restrictions.

This necessitated removal of the chains, cabling and monitors for them to be sent back to the manufacturer. Eventually some modifications were made to the system in the form of the new firmware and external resistors. This has seemed to cure the problem.

11 PRELIMINARY FINDINGS

At the time of writing there is still much data to be analysed and interpreted and several anomalies need to be solved. Preliminary findings are as follows:

- The internal temperatures track the external temperatures very closely, indicating very little thermal lag. Despite the designer's belief that the building has considerable thermal mass, this is in fact not so. The floors of the offices are carpeted and the undersides of concrete slabs are covered by plastered false ceilings. The floor of showroom is available as thermal mass but is small in comparison to its volume.
- There is a marked degree of stratification of the air in the showroom and spares stores possibly indicating relatively stagnant air without sufficient air movement.
- The weather data reveals a much higher than expected component of wind from the WSW and SW and as opposed to the macro-climatic wind flows which are from the NNW to NNE direction.
- There is, at times, as much as a 4,5°C Δt between the temperature measured at the

weather station and the building itself, indicating air flowing over the paving can pick up considerable heat which is not cooled by the small amount of vegetation in front of the building.

12 SHORTCOMINGS OF THE CASE STUDY

Probably the major short coming of the study was that insufficient data was gathered on the air flows inside and around the building. Due to financial constraints only a single hot-wire anemometer was available and the period of monitoring was too short.

If the weather station had been equipped with radiation (both direct and diffuse components) it would have made interpretation of data easier and more accurate.

The lack of calibration of some items is seen as a shortcoming.

12 ACKNOWLEDGEMENTS AND THANKS

The staff and management of Miele South Africa is thanked for the willingness to allow the University to conduct this study and for accepting the inconvenience of students disturbing their work. Special thanks must be given to Mr Frank Vos, the General Manager for his role and facilitation of the study.
Thanks to the Department of Architecture of TUT for additional funding when funding from research budgets was insufficient. Thanks to Mr Paul Carew of PJ Carew Consulting for advice and engaging in debate.

13 REFERENCES

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