Energy
Water
Green Building

Sustainability Handbook 2020

Volume 1

South African Council for the Architectural Profession

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Ed's Note

This Sustainability Handbook is being brought into being in the grips of a major disruption in the form of a microscopic havoc-wreaker. Covid-19 has produced an unwelcome natural experiment. At least temporarily, it has brought whole economies close to standstill and is raising some very uncomfortable questions, not so keenly asked in the heady, heedless pre-corona times, and shedding new insight into possibilities of change.

Since we have been stopped in our tracks, is it desirable or even possible to return to the solace of old routines and habits? Is this the needed seed for transformative change? Can the legacy of this devastating pandemic somehow – at least – be instrumental in putting us into a sustainable trajectory, of ushering in a world of greater justice, equity and inclusion?

In the thought piece, When Corona Met Climate: The Covid-19/Climate Change Nexus, Llewellyn van Wyk presents a review and discussion of commentaries which he is collecting and collating. These cast light on uncertainties, the range and variety of responses to and speculations on the early and expected impacts of coronavirus and climate change.

Whilst most of the contributions published in this collection predate the rise to awareness of the viral threat, three anticipate the focus on health services. One chapter discusses the piloting of a customized green star rating tool for a hospital in Pretoria, whilst another examines the suitability of hybrid design strategies applied in the Hillside Clinic, in Beaufort West. The third chapter with a health theme discusses the public health issues emanating from one common building material used historically, but not yet effectively cast out of our built environments. The chapter discusses the role of industry in advocating the use of the toxic material, even in the face of mounting evidence against its use, describes the inability of legislators to act swiftly and decisively. It appeals to professional peers to learn these valuable lessons from history and to avoid tacit endorsement through failing to exercise duty of care and unwitting complicity in causing harm to our fellow citizens. A chapter on the environmental benefits of telecommuting is prescient in anticipating a shift from an office-centric work locus to one which is suddenly driven to experimentation and open to reimagination, enabled by the integration of ICT into the built environment and ignited by a new imperative to maintain physical distance.

Whilst coronavirus wreaks new havoc, the long-standing challenges posed by natural resource depletion (e.g. water) and energy generation capacity, if not intensified, continue unabated. Case studies published in this handbook compare and critique two methods for sizing rainwater-harvesting systems and assessing the benefits of installing a photo voltaic solar system in a private dwelling. Given the existing and certainly intensifying pressures on the most vulnerable in our communities, the chapter on the potential for SMMEs to benefit from renewable energy initiatives, is poignant.

Academics at Nelson Mandela University and Free State University have discussed work which is informing student activities which engage local communities and investigate factors in the management of human settlements for human settlements, as well as explore Post-Natural Building and Eco-Vernacular Architecture as approaches for mediated self-help housing in contemporary South Africa, based on available and waste materials. Another capacitation initiative is featured on building code training programme offered to local metropolitan regulators on SANS 10400 XA, and poised to scale-up.

I hope that readers derive as much pleasure from this eclectic anthology as I have had in curating it. The CSIR has long held an important role in bridging gaps between academia, policy and legislation and industry and practitioners. With its inclusive and un-themed content, The Sustainability Handbook provides a glimpse into the diversity and multiplicity of questions and approaches which interest and occupy the various professional endeavors of our time and place. When I don't feel daunted, I feel blessed and thank outgoing editor, Llewellyn van Wyk, for passing the baton to me on his retirement to New Zealand to continue the work started in the 12 preceding editions of the Green Building Handbook. I am deeply grateful to the peer reviewers who have constructively engaged with material to provoke and critique chapters. Each refereed article has had at least two independent, blind reviews and these were turned around at record pace. The reviewers are recognized and emerging experts in their respective fields and their credentials are impressive. Finally without the contributions of academics, colleagues, practitioners and professional peers who have written the pieces, the Handbook would not be possible.

Peta de Jager

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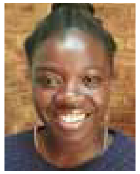

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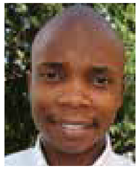

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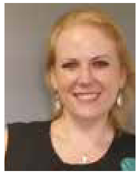

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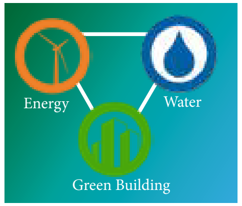

The
Sustainability Handbook
Volume 1

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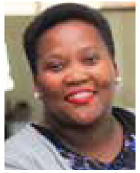

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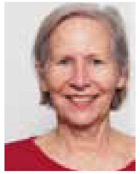

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PEER REVIEW

Alive2green has introduced and is committed to peer reviewing a minimum number of published chapters in all Sustainability Series handbooks. The concept of Peer review is based on the objective of the publisher to provide professional, academic content. This process helps to maintain standards, improve performance, and provide credibility.

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- Relevant and extensive coverage for advertisers within the handbooks and online.

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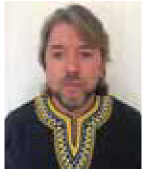

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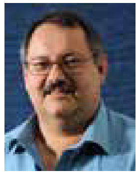

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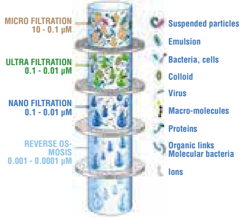

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The capacity of the tank for treated water accumulation and supply to the consumer	1000 l
The flow rate of the pumping facility for water supply to the consumer	3 m³/hour
Room size	3.52 x 2.45 m
Installed capacity	5.5 kW

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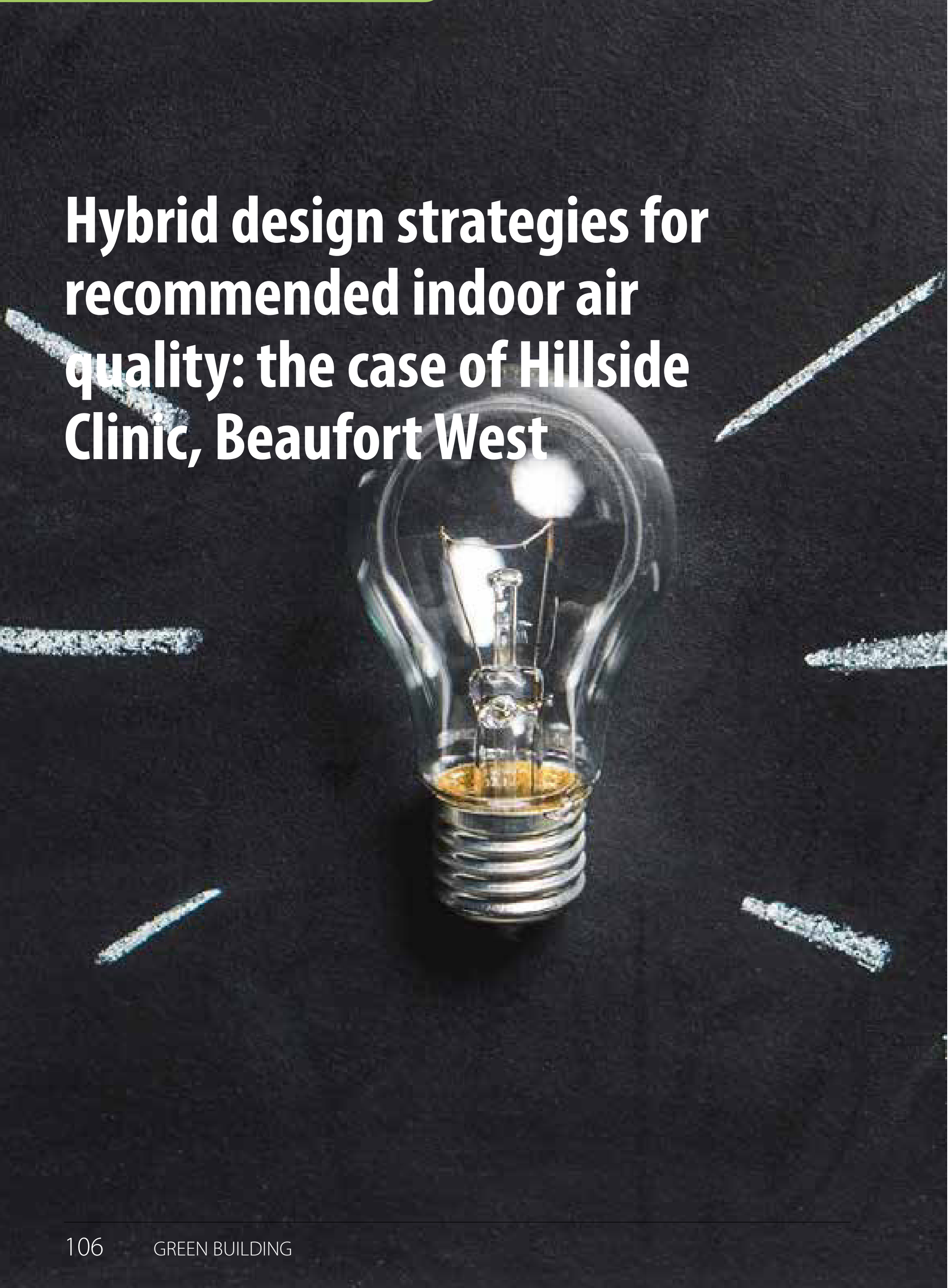
Hybrid design strategies for recommended indoor air quality: the case of Hillside Clinic, Beaufort West



1. Introduction

The high occupancy that typically occurs in South African clinics, and the accompanying risk of air-borne infection, make ventilation and thermal comfort particularly important considerations in the design.

Passive (natural) ventilation offers a low-cost, energy efficient alternative to mechanical ventilation to dilute air, decreasing the concentration of contaminated particles (Nice et al., 2015). However, the performance of natural ventilation is variable and its success is reliant on constant monitoring.

Passive design takes advantage of local environmental and climatic conditions to provide lighting, thermal comfort and ventilation, with the principal aim of minimizing the energy consumption and subsequent carbon footprint of a building (New Zealand Ministry of Education, 2017). The following case study considers the efficacy of a hybrid (passive and mechanical) design strategy to achieve suitable indoor conditions for a healthcare facility.

The Hillside Clinic, Beaufort West, was completed in 2017 by the Western Cape Government (WCG) Department of Transport and Public Works, for the WCG Department of Health (the end user). The design brief set out to achieve a suitable indoor environment for a healthcare facility, while challenging designers to consider green building principles, a zero-emission design, and affordability of construction and operation within the specific context. The appointed consultants responded with a number of passive design strategies, including, amongst others, the installation of rock-bed thermal stores and attention to the building envelope materials. These passive techniques were supplemented with mechanical ventilation systems to form a hybrid design. The authors conducted an independent study of the performance of the facility, a year after completion.

Beaufort West is situated in a relatively extreme climate, currently classified as cold arid desert, with high diurnal and seasonal temperature differences. Assuming a 2 °C global warming, it is predicted that this area will become a hot arid climate. Furthermore, the area of South Africa resembling the current Beaufort West climatic conditions could increase by up to 16% (Engelbrecht and Engelbrecht, 2016). The Hillside Clinic thus provides a useful study precedent for the application of hybrid design principles applied in healthcare buildings in these arid climates in South Africa. While stating a preference for natural ventilation, the client's brief recognised that conditioned, mechanically driven air is necessary to achieve the required ventilation rate in certain areas where 100% ducted fresh air supply is recommended.

1.1. Objective

The goal of this research was to provide evidence on which to optimise passive design strategies with minimal or no hybrid supplementation for future healthcare facilities in existing and emerging extreme climates in South Africa.The objective of the case study was to evaluate the indoor air quality (IAQ) of the clinic relative to local and international standards and guidelines for healthcare facilities and evaluate the suitability of the strategies employed for a clinic design in a relatively high heating and cooling demand climate in South Africa. The Hillside Clinic in Beaufort West was identified as an ideal case study as it met the selection criteria in terms of climate and facility type.

1.2. Research method

Both qualitative and quantitative data collection was performed at the facility.

The IAQ in terms of carbon dioxide (CO2) concentration and air temperature was evaluated during operation of the facility. Temperature (indoors and outdoors) and CO2 levels were measured at five-minute intervals over at least 24 hours at various locations at the clinic during mid-summer (December) 2017 and in mid-winter (June) 2018.

Structured interviews were conducted with patients and staff, using the Western Cape Health Infrastructure Post-Occupancy Evaluation template, to assess the perceived comfort of the users. These interviews were conducted one year after the opening of the facility.

2. Climate considerations

The climatic location and orientation of a building influence the thermal comfort within the building, as well as the building envelope design since a significant amount of heat is gained or lost through the envelope. This was aptly considered when establishing the orientation and the design of the external envelope of the clinic.

2.1. Annual Heating and Cooling Demand

According to the Annual Heating and Cooling Demand reference map (Figure 1) created for the revised South African Bureau of Standards standard SANS 10400-XA, Beaufort West falls within a Medium Heating and Medium Cooling zone (Conradie, Van Reenen and Bole, 2015). This places the clinic in a relatively extreme climate with maximum diurnal temperature variations of 20 °C (13 °C average diurnal variation).

An analysis of Beaufort West weather files, generated by the Meteonorm software, indicates that a building with a base temperature of 18 °C requires 32 222 Heating Degree Hours (HDH) and 22 145 Cooling Degree Hours (CDH).

Thus on average 46% more heating energy than cooling energy is required. The project design team came to a similar conclusion, designing predominantly to prevent heat loss (Louw, 2017, p 31).

2.2. Solar protection

The clinic building is oriented 17.5° east of north. According to a post-design solar analysis by the CSIR, the following hours of solar exposure can be expected on each façade annually: northern: 3 925; eastern: 2 998; southern: 1 592; western: 2 518.

A bioclimatic analysis with Climate Consultant v6.0 calculated that there would be benefit in sun shading of windows for 1 107 hours per year and that by using purely passive design strategies, comfort can be achieved for 72.8% of the year (6 383 out of the total annual 8,766 hours).

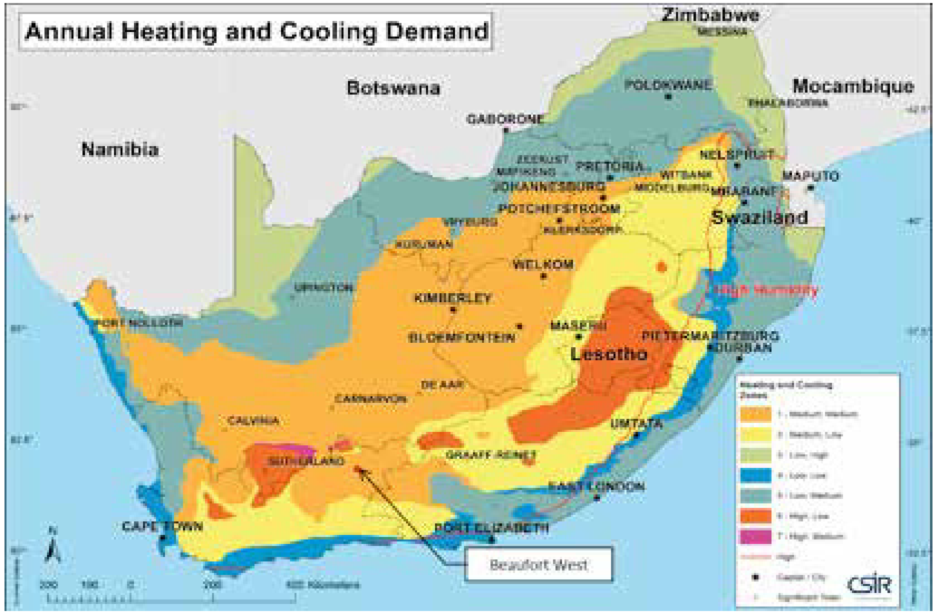


Figure 1 Degree-day based building energy reference map for South Africa (Conradie, Van Reenen and Bole, 2015)

3. Building performance: Indoor air quality (IAQ)

Indoor air quality refers to the level of airborne contaminants in the indoor environment as well as the temperature and humidity of the air. In this clinic, where the primary indoor air contaminant is exhaled breath, the difference between indoor and outdoor CO_2 levels can be used as an index of the indoor air quality and the fresh air ventilation rate.

3.1. Fresh air requirements

Fresh air is supplied by ventilation, which may be by either passive or mechanical means or a hybrid combination of both. Passive ventilation relies on the air pressure differential between ventilation inlets and outlets, or on vertical height and thermal differentials within building spaces (the 'stack effect'), to drive air movement (Clancy, 2011). Because of variable outdoor temperature and wind pressure, achieving a constant ventilation rate using only passive means is not possible. Thus, a hybrid solution is better suited to a facility where a constant minimum ventilation rate is required.

Air quality in a clinic is particularly important in spaces presenting high occupancy and duration of occupancy, such as waiting areas, contributing to a higher risk of infection. In healthcare environments, the spread of airborne pathogens is a primary concern.

This is of particular relevance in South Africa, where the Tuberculosis (TB) prevalence is high (Kanabus, 2018). An adequate supply of fresh air ensures constant dilution of room air, reducing the concentration of contaminants in the air and thus the risk of airborne infection. According to the World Health Organisation (WHO), the recommended fresh air delivery rate for high risk mechanically ventilated spaces is 80 litres per second per person (L/s/p) (World Health Organisation (WHO), 2009b). This rate should be doubled where only natural ventilation is employed to account for the variability of natural ventilation (World Health Organisation (WHO), 2009a).

The concentration of CO2 in indoor air, compared to the outdoor concentration, gives an indication of the amount of re-breathed air in the space and the risk of respiration derived pollutants. Thus, the CO2 concentration differential is a passive indication of IAQ without directly measuring ventilation rates. In enclosed spaces, normal respiration rates of occupants will naturally increase CO2 levels above external atmospheric levels.

The limiting concentration of CO2 indoors, which is indicative of acceptable transmission risk, is independent of the number of occupants in that space, as increased occupancy levels will demand a corresponding increase in the ventilation rate, essentially resulting in constant CO2 levels. Assuming a respiration rate of 10 L/minute per person, 80 L/s/p equates to a CO2 limit of 79 parts per million (PPM) above ambient levels.

3.1.1. Fresh air findings

The ventilation strategy employed in the design of the Hillside Clinic is a combination of natural ventilation via openable windows and a ducted mechanical system providing tempered fresh air. Low winter temperatures and high winds are conditions that lead occupants to close the windows. Thus, the concurrent mixed mode system used is appropriate to ensure the required ventilation rate is maintained. Ducted tempered fresh air is supplied to all clinical spaces and cascades to passages, from where it is extracted.

These wide single-sided passages, with extensive glazing on the northern side, provide direct access to the consulting rooms and also serve as sub-waiting areas. Sliding doors and high-level manually openable windows provide opportunity for natural ventilation, although the sliding doors often remain locked due to security concerns.

The main waiting area is sufficiently narrow to allow for natural cross-ventilation, however, windows here are not openable and the sliding doors remain locked. Instead, constant ventilation is provided by means of a ducted 100% fresh air supply, therefore air is not re-circulated and contains no contaminants from sources within the building. Air intake from outside is via high ventilation chimneys (Louw, 2017a), minimising the possibility of entraining hot air from the roof or dust and other street level contaminants.

The measured CO2 levels indicate the ventilation performance. Data collected in winter (considered the worst-case scenario) in the main waiting area with doors closed showed a maximum CO2 concentration of 581 PPM (against an outdoor reference level of 400

PPM). This equates to 35 L/s/p, which is not within the WHO limit for airborne precaution environments but exceeds the per person requirements of the National Building Regulations for non-clinical waiting rooms. Air changes per hour could not be directly inferred from the available data.

3.2. Thermal comfort requirements

Thermal comfort, though subjective, may be considered to be achieved indoors at air temperatures of 21 – 24 °C for mechanically ventilated spaces in healthcare facilities (Ninomura et al., 2013). Adaptive comfort models applied to naturally ventilated spaces offer a wider temperature range of 19 – 29 °C which changes seasonally (ASHRAE, 2017).

3.2.1. Thermal comfort findings

The measured room air temperature recorded during occupied hours (8 am to 5 pm) in summer was 21 – 29 °C and in winter, 10 – 24 °C.

The designers employed both thermal mass and glazing in the envelope to achieve thermal comfort passively.

The walls on the northern façade have large glazed sections with roof overhangs calculated to prevent summer solar radiation yet allowing maximum winter heat gain in the sub-waiting areas. The temperature measured here during winter was 15 – 22 °C, up to 10 °C warmer than the outdoor temperature and within the 19 – 29 °C comfort range for 55% of the operational hours. The same area showed a temperature range of 21 – 27 °C in summer, with the glazing shaded from direct sunshine. The southern façade is constructed using 600 mm thick rammed earth walls to minimise heat transfer in summer (Louw, 2017a). Air temperatures measured either side of the rammed earth wall testified to the expected performance in summer, reducing the heat transfer to the building interior by up to 10 °C during the hottest hour of the day. The southern windows are shaded in summer by roof overhangs, preventing direct solar radiation. The ceiling void is insulated at the ceiling level as well as over the purlins, while ventilation openings along the eaves and ridge reduce heat build-up in the ceiling void which could affect the air temperature in the ventilation ducts located in the ceiling void. Where there is no ceiling void (in the passages where there is a raked timber ceiling) a high density closed cell insulation board is used between the ceiling panels and the purlins.

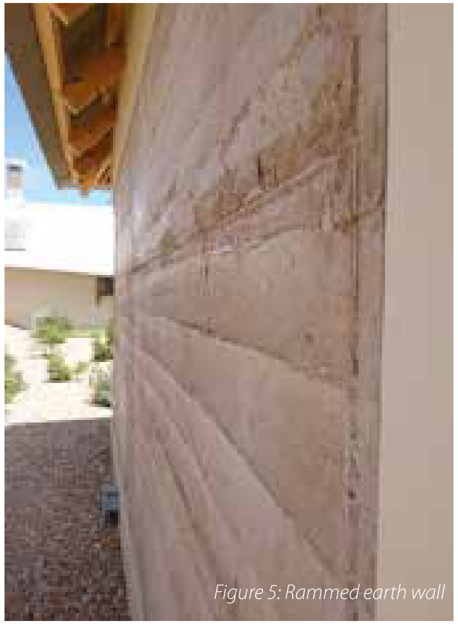


Figure 5: Rammed earth wall

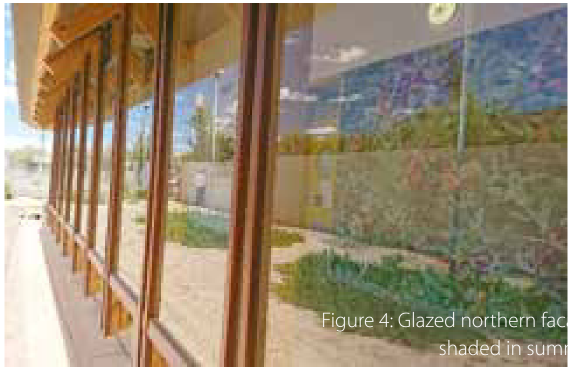


Figure 4: Glazed northern fac
shaded in sum

The temperatures recorded are not wholly indicative of the effectiveness of the envelope design since the room air temperature is influenced by the temperature of the ducted air supply. The supply air is passively conditioned by passing it through a rock-bed thermal store, to reduce the need to use energy for heating or cooling (Louw, 2017b).

During summer, warm outside air is drawn in from the chimneys using fans and circulated through the rock-bed thermal stores beneath the building. The rocks pre-cool the air supply to the building. The rocks are recharged (cooled) during the evening when the outdoor air temperatures are cooler, in preparation for the following day. Conversely, in winter the rocks are warmed (relatively) by outside air passing over them during the day. At night the ventilation is shut off to retain the day-time warmth in the rocks in order to be used to temper the cold morning air the following day. This system is theoretically well-suited to the high diurnal temperature differences of Beaufort West.

The system was found to be effective in summer, with a consistent supply air temperature reduction of 8 – 10 °C being reported. However, at the time of this study, the system was not being operated correctly during winter, being left permanently in summer mode. This resulted in the rock bed being cooled during the cold winter nights.

Though the central ventilation system seems to provide sufficient fresh air, the thermal comfort is supplemented by wall-mounted split unit air conditioners in the consulting rooms and the staff room. These were observed to be in use in both summer and winter. Temperature data in areas that did not have split units (e.g. waiting area) showed that, when used correctly, the passive heating and cooling systems can significantly reduce the facility's annual demand for mechanical heating and cooling energy.

Interviews with staff and patients revealed a correlation between the performance data and user experience. Staff reported acceptable thermal comfort during the summer months with limited need for further cooling. The cold winter months were however reported to be uncomfortably cold, particularly in the early mornings. The main waiting area was the biggest cause for concern as it relies solely on the performance of the rock-bed thermal stores. Patients interviewed in the afternoon reported comfortable thermal conditions. Overall, staff and patients felt the facility was pleasant and responded well to the operational needs.

3.3. Operation and management

During the assessment of the facility building systems, it became apparent that all the building systems were not operating optimally.

The rock-bed thermal store was operated in an incorrect seasonal mode. The provision of split-unit air conditioners gives the impression that the rock-bed thermal store system does not provide sufficient warming or cooling of the supply air. This perception might easily be remedied by correcting building operating practices. Once the control setting of the ventilation system has been remedied, the thermal comfort levels in the affected areas should also improve.

In addition, the importance of setting aside time and funding for an extended commissioning and system tuning period cannot be stressed enough. Innovative passive design strategies that provide natural thermal comfort, such as rammed earth walls and rock-bed thermal stores, demand additional contractual (and monetary) considerations for post-completion monitoring and adjustment. This should at minimum include a 12-month seasonal cycle commissioning period, to ensure proper system functioning and operation.

4. Discussion and Conclusion

The positive feedback from users of the clinic, both patients and staff, is a clear testimony of the perceived positive health experience of the building and the user comfort success of the design.

Passive strategies employed in the design include the orientation of the building to maximise solar heat gain in the cold months, correctly calculated roof overhangs to prevent heat gain through glazed elements in summer, selective use of thermal mass to minimise heat gain in summer, ceiling insulation to minimise heat transfer through the roof, and rock-bed thermal stores to pre-condition the fresh air supply. Though the facility cannot be considered fully passive due to the use of ventilation fans and air conditioners, the principles employed in the envelope material choice, the rock-bed thermal store and the roof overhangs improve the comfort and energy efficiency of the facility.

Managing user expectations and behaviour in passive buildings is an essential component of any similar project. Established design practices overlook the importance of developing, communicating (training) and testing control regimes. System descriptions and operation procedures should be developed to cover all operational modes.

Demonstrations and training of users will support and promote effective usage.

Modelled predictions suggested that this clinic can achieve suitable IAQ by fully passive means alone. An analysis of room air temperatures in areas that do not have split AC units, indicated that thermal comfort can be expected for the majority of the time during operating hours. Split unit air conditioners in selected areas, installed as part of the original design, suggest little confidence by the designers in achieving effective thermal comfort conditions by passive means alone, though it is possible. The use of air conditioners could be attributed to the preferences or expectations of the users.

The use of rock-bed thermal stores to temper fresh air was successful under correct operation, though improved operation of the system is required to optimise its year-round potential. Feedback and monitoring during the first 12-month operational cycle has been essential for identifying the operational shortcomings and inefficiencies, which can now be corrected.

The excessive use of split units to condition the air, and the incorrect operation of the rock-bed thermal stores highlight the importance of good commissioning and operational management. This is particularly necessary when passive measures are employed, which are not as predictable or controllable as mechanical measures. Correct operation after handover cannot be assumed without thorough user-training and a documented handover process.

It is thus essential that user engagement at all levels be prioritised throughout the passive or hybrid design and development process, and revisited at various stages post-occupation.

Measured CO2 concentrations converted to L/s/p suggested that during summer months there would be an adequate supply of fresh air in the facility, particularly in the waiting room, which is typically the highest risk area. It can thus be concluded that, correctly operated, the quality of air within the facility reduces the risk for airborne contagion such as TB. This conclusion is supported in that the staff reported that no healthcare workers have contracted TB in the new clinic.

Though the building is not wholly passive, it is a decisive step towards an energy-efficient approach to healthcare facility design. The evidence collected demonstrates that a hybrid design that uses both passive and non-passive environmental controls can achieve suitable indoor conditions for a healthcare facility, though the importance of commissioning and operational management is essential to ensure efficacy.

The Hillside Clinic therefore serves as a useful reference design for future clinics in similarly extreme climates, as well as more temperate settings. With the objective of design refinement to achieve a truly passive design, future designs based on the principles employed here would benefit from further research targeting performance improvements.

The noble objective set by the Western Cape Government to develop a green clinic must gain traction throughout South Africa as the built environment sector seeks to improve sustainability and build resilience to climate change.

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Project Team:

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6. Declaration of Interest

The authors hold no financial or technical interests in the design, construction or operation of the facility and conducted the study as an independent exercise. Findings from this study were incorporated as part of the facility's post occupancy evaluation.

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