7.1 Introduction

One of the primary functions from a technical point of view is that the design should function as a hybridisation of systems rather than trying to be completely self sustaining.

The reasons for this approach are elaborated upon in the closing of this section. It will suffice to say that it was the author’s intent to recognise existing infrastructure, while simultaneously trying to alleviate the dependency on these systems.

7.2 Water storage

The approach to water storage on site attempts to alleviate the dependency on a Municipal connection rather than trying to be totally self-dependent. As such, all the water closets make use of stored rainwater in the months that water is available. This water can also be utilised for irrigation purposes.

The water from the entire roof structure is transferred to the western side of the building where the ‘external’ service core is situated.

All the ablution facilities have been allocated to this side of the structure to ease the utilisation of rain water.

It is envisaged that water storage tanks on an elevated platform will be hidden from view with expanded metal mesh. They will be elevated to such a height that no pumping is needed to fill the water closet cisterns as they continuously empty. On both the first and second floor the size of the water tank is 5 500ℓ and on the ground floor two storage tanks with a capacity of 5 500ℓ each are situated. There is also a 5 500ℓ tank in the basement for HVAC purposes (which will be discussed in the following section). The total water retention capacity for the building is thus 27 500ℓ.

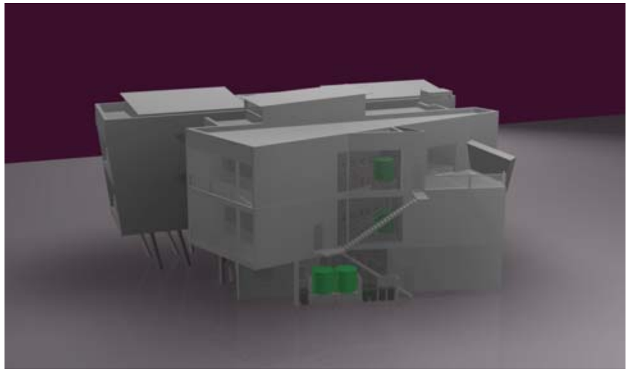

Figure 7-1: Water Storage Tanks
(Source: Own Image)

Table 7-1: Rain water harvest calculations

Month	Precipitation (mm)	Area (m^2)	Total acquired (ℓ)	Left from previous month	Used in toilets per month	Used on irrigation per month	Used for HVAC system	Surplus or deficit	Amount lost as runoff
January	136	77 071.20	77 071	27 500	26 700	9 000	924	27 500	40 447
February	75	42 502.50	42 503	27 500	26 700	9 000	924	27 500	5 879
March	82	46 469.40	46 469	27 500	26 700	9 000	924	27 500	9 845
April	51	28 901.70	28 902	27 500	26 700	12 000	924	16 778	0
May	13	7 367.10	7 367	16 778	26 700	0	924	-3 479	0
June	7	3 966.90	3 967	0	26 700	0	924	-23 657	0
July	3	1 700.10	1 700	0	26 700	0	924	-25 924	0
August	6	3 400.20	3 400	0	26 700	0	924	-24 224	0
September	22	12 467.40	12 467	0	26 700	12 000	924	-27 157	0
October	71	40 235.70	40 236	0	26 700	9 000	924	3 612	0
November	98	55 536.60	55 537	3 612	26 700	9 000	924	22 524	0
December	110	62 337.00	62 337	22 524	26 700	9 000	924	27 500	20 737
Total	674	NA	NA	NA	320 400	78 000	11 088	N/A	76 908

Table 7-1 presents a calculation of the amount of water that can be retained and shows the months in which no potable water will be wasted through water closets, irrigation or HVAC usage.

It is shown that for at least seven months of the year the building will be self sufficient regarding the usage of water in the water closets, irrigation and HVAC.

7.2.1 Assumptions regarding the calculations

The calculation of the amount of water required as a result of water closets assumed that at maximum occupation, each occupant uses the toilet at least once while in the building. Calculated according to SANS 0400 it resulted in a maximum occupation of 264 persons, as shown in Table 7-2. The dual flush cisterns flush at either 3ℓ or 6ℓ giving an average of 4.5ℓ per flush.

It was also assumed that the fact that the SAMF will only occasionally utilise the building over weekends and therefore the total weekly usage will be between 70-75%. Thus

$$264 \times 4.5L \times 0.75 = 891L$$

This over a month (30 days) works out to approximately 27 600ℓ.

The irrigation calculation assumed that each square metre would require 1ℓ of water per day. It was also assumed that in the rainy season the irrigation requirements would be half this number as the soil would receive natural precipitation. If there is ±600m² of landscaped area the calculation becomes.

$$600m^2 \times 30days \times 0.5L = 9000L$$

The monthly requirement is thus 9 000ℓ except for the dryer months where the natural precipitation is under 70mm, where 12 000ℓ was utilised. It was decided not to irrigate the landscape over the height of winter, May June and July, as water is scarce and it would contradict the environmentally sensitive approach of the building.

The HVAC water requirements are discussed later under mechanical ventilation. For the purposes of this table it 88ℓ per day was used.

The HVAC system will rarely be used for the auditorium over weekends and occasionally in the week therefore an average of 21 working days is considered a liberal estimate of usage. It is also important to note that for the purposes of this calculation the assumption was made that 50% of the water will be recycled in the HVAC unit which would decrease the usage further.

$$88L \times 21days \times 0.5 = 924L$$

The HVAC requirements are thus 924ℓ per month. It is interesting to note is that with the installation of a further two 5 500ℓ tanks at a later stage, the deficit can be negated and the building can become completely self sufficient regarding water closet usage irrigation and HVAC requirements.

It is foreseen that this could be done in one of the basement levels with solar powered submersible pumps to move the water higher as the need arises.

Although 50ℓ geysers are provided on each level they operate in conjunction with a solar water heater on the Western Roof. The intent is to have them activate only if the temperature is below 50° Celsius.

7.3 Ventilation

As stated above, one of the primary functions from a technical point of view is that the building should function as a hybridisation of systems rather than trying to be completely self-sustaining.

As such there is both a system of natural ventilation and an HVAC system employed in the design. The exterior shape of the building, although generated from the fractal geometry as discussed in Chapter 6, was still utilised in such a way that natural ventilation remained possible. The design deliberately tries to move away from utilising a HVAC system, however it was deemed necessary for the 73.6m² auditorium and the server room of 6.3m².

7.3.1 Mechanical HVAC system

The 90 seater auditorium is the only venue that cannot be serviced with natural ventilation as it is completely windowless. The Auditorium is situated directly one storey above the plant room, in Basement -1. This design decision was made to simplify the installation while creating enough distance from the air intake to reduce noise ingress. Calculations regarding the air flow requirements are as follows.

Figure 7-2: HVAC-System Ducting
(Source: Own Image)

According to the SABS 0400 the amount of air required per person in public hall of this nature is 3.5ℓ per second per person. For an auditorium of this size (90 persons) this translates to 90 x 3.5ℓ = 315ℓ per second per person, or then 0.315m^3/s.

In the following formula:

$$V = \frac{N.v}{3600}$$

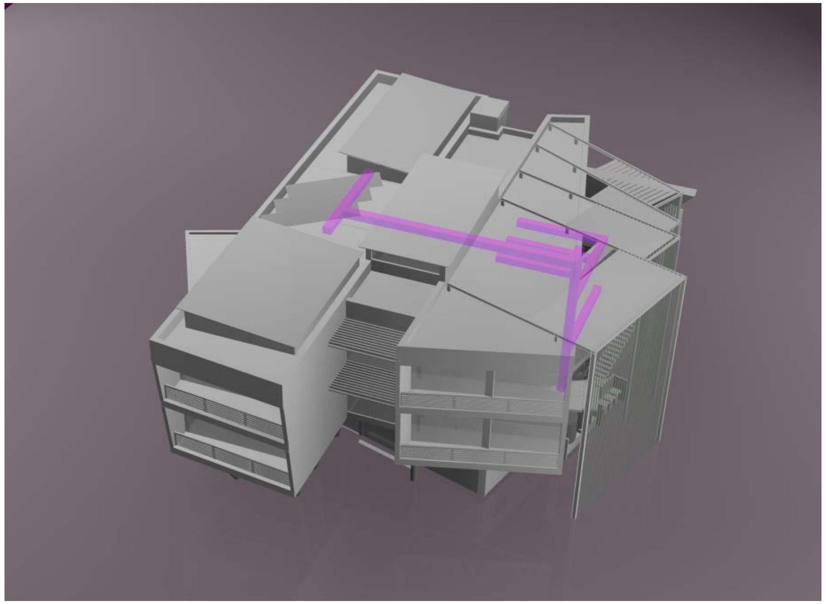

Figure 7-3: HVAC-System Ducting
(Source: Own Image)

Where V= Rate of airflow in m^3/s ($0.315m^3/s$)
N= Amount of air changes per hour
v= Volume of the room ($294.4m^3$)

$$0.315m^3 = \frac{N.(294.4\,m^3)}{3600}$$

N equates to 3.8 air changes per hour. An air change of between 1 and 10 is within limits.

The real question however is the sizing of the duct. As the auditorium will be used mostly for presentations that involve spoken word it is important to ensure that the air change is still acceptable but that the air speed in the duct is slow enough that it does not contribute significantly to noise level in the auditorium.

For this

$$V = (0{,}6).A.v$$

Where V = Required rate of air flow (0.6 is an efficiency factor due to friction in the duct)
A = Area of the duct (m^2)
v = Required air speed

The air speed (v) can vary between 2m/s and 7m/s, but an increase in air-speed also increases the noise level due to friction. It is therefore decided that the air-speed should be 2m/s to ensure that fresh cool air quietly drops out of the ceiling duct without causing a disturbing hum. Consequently,

$$0.315m^3s^{-1} = (0{,}6).A.(2)$$

If A equals 0.2625 m² in the form of a square duct of L²=0.2625m², then L equals 510mm. This can be easily accommodated in the ceiling void of the auditorium.

A decision was taken to op for a Pulsed Power water treatment HVAC system to cool down the 80m² that is made up by the Auditorium on the second floor and the Patch and Server Room on the Third floor. This decision was taken as the Stored Rainwater could be utilised in the HVAC system and the Pulsed Power performs better pertaining to maintenance issues.

With this system in place it would require 1.1 litre per day per square metre if the system runs for 12hours per day for 5 days per week. For the total 80m² it would thus require 88ℓ of water per day. It is however foreseen that the auditorium will not be in constant use and therefore the usage will be much lower. It is also deemed unlikely that the HVAC system will be run for cooling purposes in the auditorium in the winter months. In all probability it will be run only to ventilate.

Another question that arises is the energy usage of the HVAC system. It is possible to calculate that to cool the 80m² of floor area would require a 5.27 kWh system. This translates to between a 1.55kW - 1.8kW unit. It is important to note that the efficiency of an HVAC system increases the longer it is left on.

For explanation purposes this means that the 1.550kW system will be running at full output for an actual 3.4 hours per 12 hours. Of course it is running at a lower output for a longer period.

The cooling capacity of this unit at its maximum power output of 1.8kW would translate into a 4.6°Celsius drop in temperature per hour. The following calculation serves as an explanation.

$$q = 1250.V.(T_0 - T_i)$$

Where q = Power output in Watt
1250 = Volumetric heat capacity of air
V = Rate of airflow (calculated earlier as $0.315m^3$)
T_0 = Outside temperature (in Kelvin)
T_i = Inside temperature (in Kelvin)

Thus

$$1800W = 1250.(0.315M^3).(T_0 - T_i)$$

$(T_0 - T_i)$= 4.6° Kelvin (or Celsius)

If the unit is run for one hour at 1800W, it means that it reduces the air temperature by 4.6°C per hour.

If one correlates this with the average daily maximum temperature in Pretoria (Table 5-1) and were to assume that the temperature inside the auditorium is equal to the outside temperature, it would take the cooling unit less than an hour to bring the temperature down to levels that are acceptable for human comfort even on a hot day (20°-24°C).

The hybrid intention mentioned earlier means that it is important to limit dependency on the Eskom grid but that it is still available as a source of energy. As stated earlier, a 5.27kWh unit will be sufficient. Most commercially available Photovoltaic units can deliver 170W/m². This means that with 12m² correctly placed Photovoltaic units over 2kW can be produced. With only 5 hours of sunshine (the average for Pretoria is 9 hours per day for 300 days of the year), 10kWh can be stored.

This can run the unit for almost 5 hours at maximum output capacity. The battery units that store this energy require ±0.5m²/kW (therefore 5m²) and will be housed in the LV room in Basement-1. The Photovoltaic Panels are installed North-Facing, on the Eastern wing as indicted on the roof plan, the intention is to be as inconspicuous as possible.

It is important to note that although the building has mechanical ventilation, *it is not* dependant on the municipal electricity supply for this. It is thus utilising existing HVAC technology where it is necessary without compromising sustainability.

7.3.2 Natural ventilation

It was decided to utilise natural ventilation in the rest of the building. This means that each floor functions on its own as a natural ventilation system, but they also connect together to form a system of natural ventilation to cool the building.It is therefore important to read Figure 7-4 to 7-9 as a whole and not as individual sketches. One aspect that enables the natural ventilation feasibility is generated from the 'air-scoop' or wing -wall that is situated on the eastern side of the building. The prevailing wind direction is thus utilised to generate enough air changes in the building's top two floors.

Wing walls are vertical solid panels placed alongside of windows attached to the wall on the windward side of the building (OSE, 2009). Casement windows offer better airflow and because awning type windows need to be fully opened or air will be directed to ceiling. It is also important to note that this 'scoop' feeds fresh air directly into the two venues that will have the highest occupation in the entire building besides the occasionally occupied, mechanically ventilated, Auditorium.

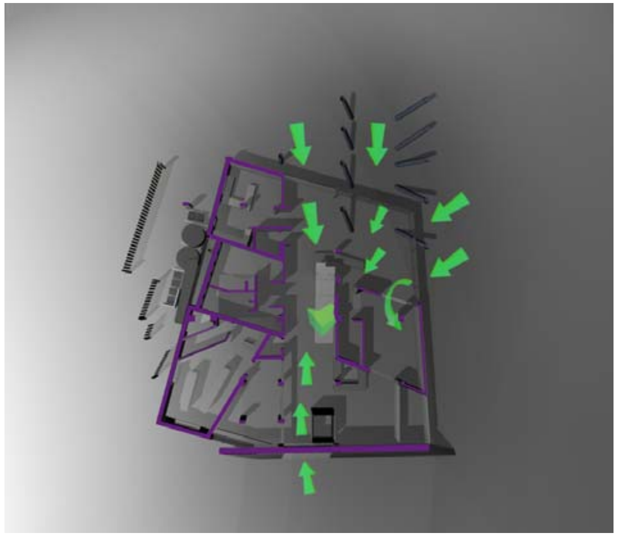

Figure 7-4: Airflow on the Ground Floor
(Source: Own Image)

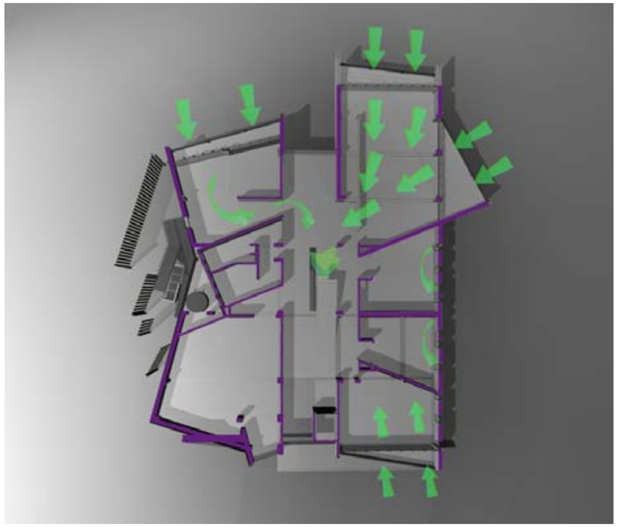

Figure 7-5: Airflow on the First Floor
(Source: Own Image)

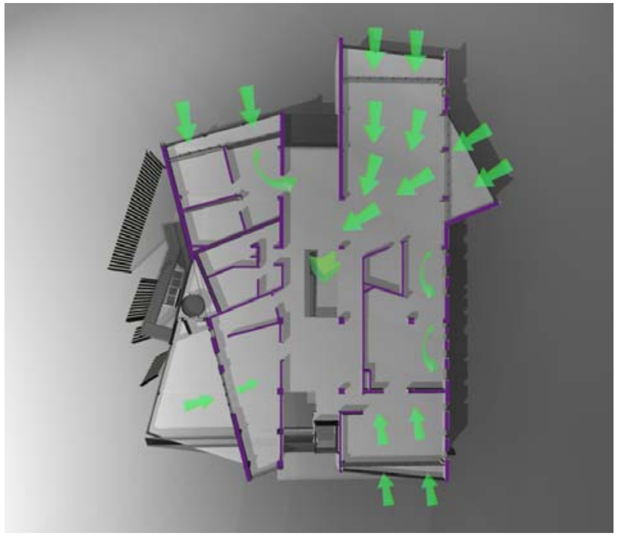

Figure 7-6: Airflow on the Second Floor
(Source: Own Image)

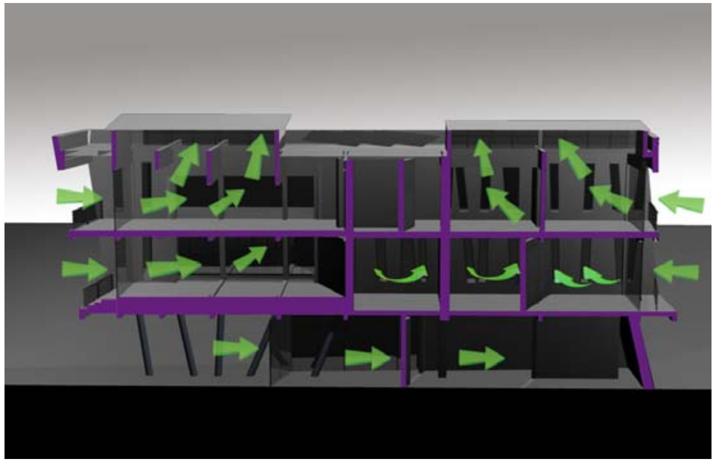

Figure 7-8: Airflow on the Western side through the clerestory windows
(Source: Own Image)

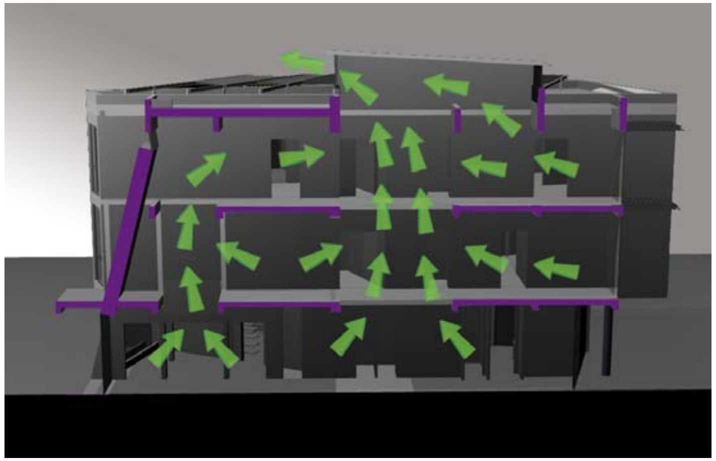

Figure 7-7: Airflow on Eastern Side between the three floors to the clerestory windows
(Source: Own Image)

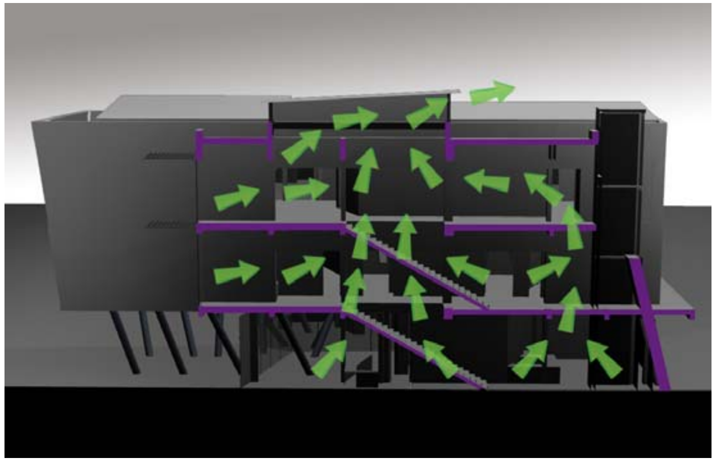

Figure 7-9: Airflow in the Central core between the three floors to the clerestory windows
(Source: Own Image)

The rest of the venues on the Eastern side are supplied with more than one window placed along the eastern wall. These are deeply recessed casement windows, as they create better airflow but need to be cognoscente of rainwater. They allow for natural ventilation that can be controlled individually in each venue. They form a cross ventilation into the central core by having openable windows next to the door. Although this compromises privacy and could create internal noise pollution, these aspects are deemed negligible in the light of the benefit of the natural cross ventilation. In the case where it is preferred to have only windows open on the Eastern façade the room one can have two widely spaced windows open instead of one window as this would increase airflow and is a natural way of controlling the amount of airflow (Level, 2009).

Single-sided, single-opening natural ventilation is effective to a depth of approximately two times the ceiling height. This implies a maximum room depth of approximately 8m, for a 4m ceiling height with a window approximately 1.8m high (Schultz, 2009).

The separate high and low openings that are used means that warm air leaves through the upper vent in the passage induces inflow through window on the Eastern side. In this situation, if the vertical separation between the openings is approximately 1.5m, ventilation is effective for 2.5 times the ceiling height although in some instances the depth could be up to 4 times as deep. This gives a maximum room depth of 12m to 16m for this scenario.

The spaces on the north-western side that require ventilation are the Exhibition space and the Private offices. These are supplied with high stacking doors that can be opened to varying openings as ventilation is required.

Although the climate of Pretoria could be considered quite temperate as winter and summer average temperature only differ by 10°C, an important aspect to incorporate into the design of a passive ventilation system is the differing design requirements between summer and winter seasons. Summer airflow requirements will be more than for winter, dictating varying openable areas in the building's skin between the extremes of these two seasons. In addition, there is an accelerated stack effect in the colder months due to the indoor and outdoor temperature differential.

Controlling passive ventilation can be manual, automatic, or a combination of the two. Based on the fact that not all the venues are occupied all the time and the design of the building that manual control would be sufficient.

A strategy to automate the clerestory windows located up high in the central core would work well while the other openings are controlled by hand. Clerestory window automation will be linked to interior temperature sensors and will thus optimise airflow. As commissioning is integral to the successful operation of any building, it is very important that natural ventilation adds to the relevance of commissioning. It is therefore highly recommended that the commissioning agent and Facilities Manager become part of the design process and the service contract be extended long past the initial occupancy to enable fine-tuning and calibration.

7.4 Shading

With regards to shading there are four important shading applications in the design.

On the Northern side care was taken to ensure that the overhangs exclude direct sunlight from spring to autumn only allowing direct sunlight with its associated heat gain in the winter months see figure 7-14 to 7-17. The respective solstice angles are 87° in summer and 40° in winter. Secondly on the northern windows that allow light into the central core shading has been provided with repurposed concrete palisade fencing. This shading is structured in such a way that the shading becomes progressively more in the summer and less in the winter (See figure 7-10 4 7-11)

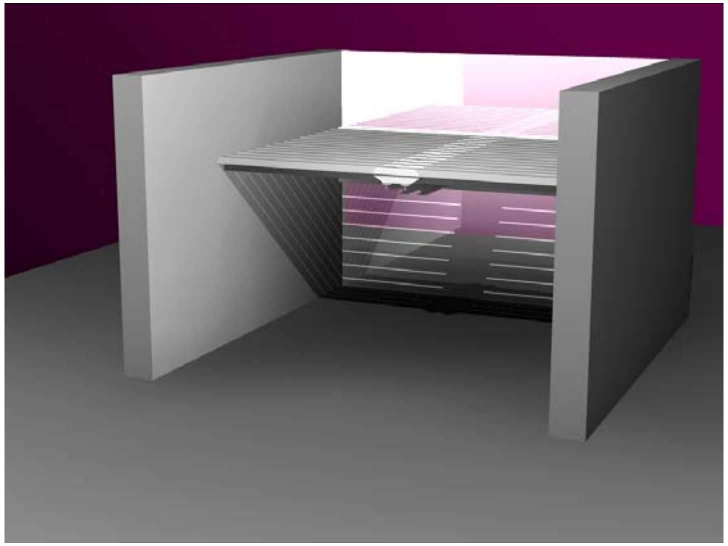

Figure 7-10: Repurposed Concrete palisades used as shading (winter) *(Source: Own Image)*

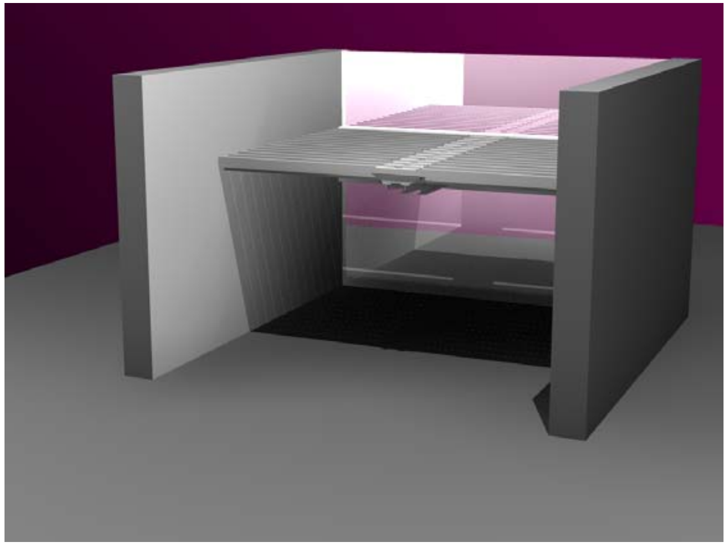

Figure 7-11: Repurposed Concrete palisades used as shading (summer) *(Source: Own Image)*

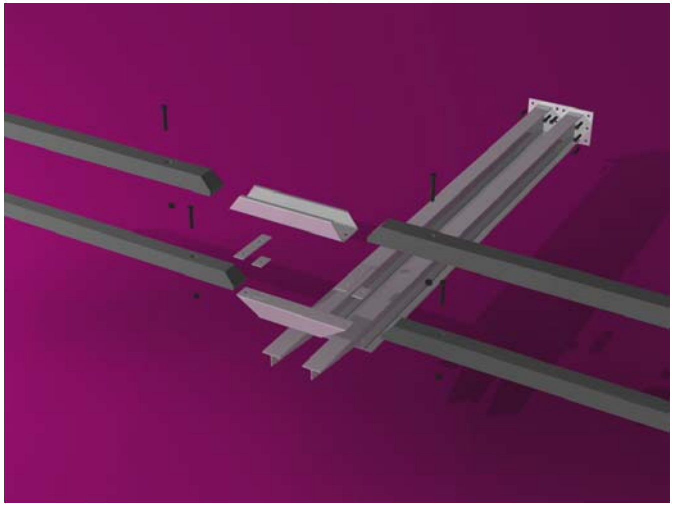

Figure 7-12: Detail of fixing of shading device
(Source: Own Image)

This was done by using the exact location of the design to calculate the spacing of the concrete palisade blocks in such away that they block out the sun in the height of summer while allowing direct sunlight in between them in winter.

Thirdly, it was deemed necessary to avoid solar heat gain on the western façade. As this façade faces directly toward the Gautrain station it was important that it is aesthetically pleasing, interesting but still effective shading.

Although there are no windows that receive direct sunlight on this façade it was still important to create effective shading. The form of the shading was developed from one of the fractals as discussed in Chapter 6.

It was decided to go for a dynamic shading device in the form of plant material and more specifically, *Rhoicissus tomentosa*.

Figure 7-13: Rhoicissus tomentosa
(Source: Sheat, 1984)

Figure 7-14: Winter noon solstice sunlight penetration on the Eastern Wing *(Source: Own Image)*

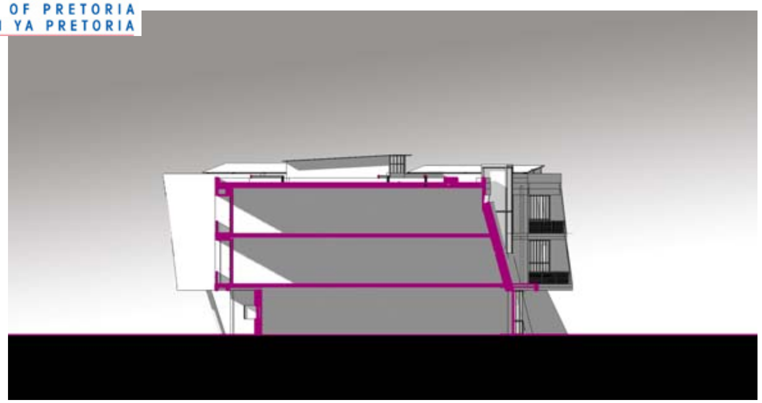

Figure 7-16: Winter noon solstice sunlight penetration on the Western Wing *(Source: Own Image)*

Figure 7-15: Summer noon solstice sunlight penetration on the Eastern Wing *(Source: Own Image)*

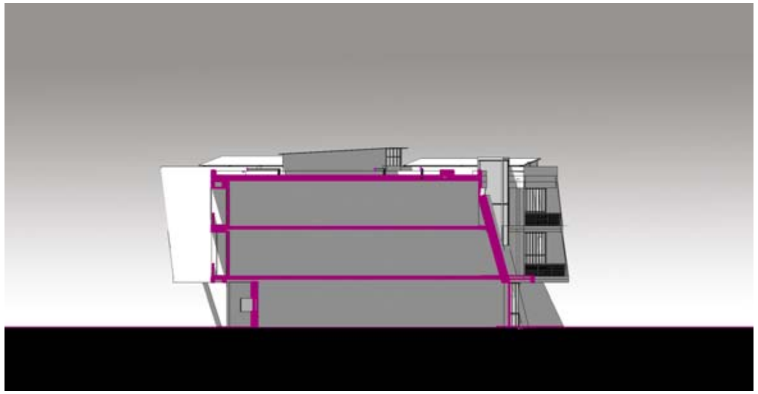

Figure 7-17: Summer noon solstice sunlight penetration on the Western Wing *(Source: Own Image)*

This Species is endemic to South Africa and can easily grow to more than 12m high with proper care (Sheat, 1984:186).

This plant with is large green leaves grows quickly and easily, and will create a green façade that is aesthetically pleasing and iconic while delivering the necessary shading to the western façade. All things considered, the shading devices work together with the passive ventilation and cavity walls to create a design that will function well thermally. It is the intent that the shading serves to enhance that passive cooling proposal and also lighten the load on the mechanical ventilation in the Auditorium.

Table 7-2: Parking and Sanitary requirements (accordi

Area Classification according to SANS	Area Specification	Required parking for that Area	Actual Area	Required Parking Spaces	Occupant Amount
A 1 Restaurant	Kitchen	2/100m	26.8	1.0	27.0
	Seating Area	10/100m	100.0	10.0	64.0
A 2 Theatre	Auditorium	1/4 Seats	71.0	23.0	90.0
A3 Places of tuition	Lecture Rooms 1	1 per 10 pupils+1 attendant	54.0	6.0	11.0
A3 Places of tuition	Lecture Room 2	1 per 10 pupils+1 attendant	54.0	6.0	11.0
A3 Places of tuition	Lecture Room 3	1 per 10 pupils+1 attendant	21.0	3.0	4.0
A3 Places of tuition	Lecture Room 4	1 per 10 pupils+1 attendant	41.0	5.0	8.0
A3 Places of tuition	Lecture Room 5	1 per 10 pupils+1 attendant	47.0	6.0	9.0
Total			**217.0**		**43.0**
C 1 Exhibtion Space	Exhibition Space	2/100 m	60.0	1.0	6.0
C2 Library		use same as lecture rooms	40.6	5.0	2.0
F2 Small Shop		1 6/ 100 m	44.5	3.0	4.0
G 1 Offices	3rd Level	4/100m	172.6	10.0	12.0
Total Parking Required				79.0	
Total Parking Provided				86.0	
Total Occupants					248
Total Sanitary appliances required					
Total Sanitary appliances required Ground					
Total Sanitary appliances required First					
Total Sanitary appliances required Second					
Total Required					
Provided					

Required Toilets	Required Urinals	Required Basins	Required Toilets	Required Basins
0.0	0.0	0.0	0.0	0.0
1.0	2.0	2.0	3.0	2.0
1.0	1.0	1.0	2.0	1.0
1.0	2.0	2.0	2.0	1.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0
1.0	1.0	1.0	2.0	1.0
1.0	2.0	2.0	3.0	2.0
2.0	3.0	3.0	4.0	2.0
1.0	1.0	1.0	2.0	1.0
4.0	**2.0**	**6.0**	**9.0**	**5.0**
6.0	**6.0**	**6.0**	**9.0**	**6.0**

7.5 Parking and Sanitary Fitting calculations

In Table 7-2, the number of parking bays and sanitary appliances that are required are calculated. In each case, the room type and its occupancy classification is shown with the relevant calculations that are strictly based upon the SANS 0400. In the instances where it is shown that a specific occupancy class has 0 requirements for sanitary appliances it is because it has been combined with another occupancy class on the same floor by adding the amount of occupants.

This can only be done in instances where the occupancy requirement is measured against the same table in the SANS 0400. In the case of the Restaurant, occupancy class A1, the staff and visitors are measured against two different tables and thus the more liberal of the two was applied to make sure that they comply.

It can be seen that the design complies in all instances with the amount of parking bays required and sanitary fittings.

7.6 SBAT Rating

As part of the Technical investigation an analysis was done to determine a rating of the sustainability of the building. The system that was utilised for this purpose is the SBAT (Sustainable Building Assessment Tool) developed by Jeremy Gibberd from the CSIR.

The tool's purpose is to provide an assessment tool that was developed within the context of a developing country for developing countries. The assessment criteria is therefore strongly related to the circumstances in South Africa.

It contains sets of objectives, divided into Economic, Environmental and Social that are measured against the extent to which these objectives are reached. This provides an easy to understand but effective measure of the level sustainability. Below are the different categories and their sub-sets that are evaluated in the SBAT tool:

Economic:

- Local Economy Input
- Efficiency of Usage
- Adaptability & Flexibility
- Ongoing Costs
- Capital Outlay Costs

Environmental:

- Water Usage
- Energy Usage
- Waste Management
- Site Management
- Materials & Components

Social:

- Occupant Comfort
- Inclusive Environments
- Access to Facilities
- Participation & Control
- Education
- Health & Safety

To the right is the Pie Chart Summary generated by the SBAT tool for this design and the final scores attained. The rating is interpreted in the following manner.

Between 0 and 1	Very Poor
Between 1 and 2	Poor
Between 2 and 3	Average
Between 3 and 4	Good
Between 4 and 5	Excellent

Although the design scores average in three categories namely: Waste, Site and Materials and Components, it does perform excellent in the Energy management sub-set of the same category.

The main reasons why the building has scored so low in the three sub-sets mentioned is due to the lack of organic and sewerage waste handling on the site, the large landscaped lawn on the north that requires maintenance,

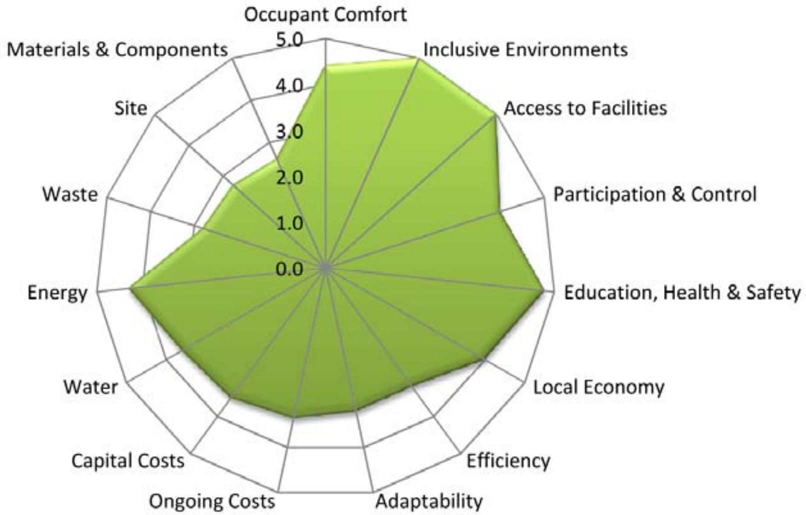

Figure 7-18: SBAT Rating *(Source: SBAT Spreadsheet)*
Final Scores: Social 4.6, Economic 3.5 and Environmental 3.2

and the fact the very little of the building material is repurposed or form organic sources. The fact that it is a loose standing very urban site has contributed to these low scores and the positive impact it will make to the area as a whole could be said to negate these average scores.

Notwithstanding these lower scores the design scores a *Good* (average of 3.8). An important fact is that the assessment reflects the intended positive social impact as outlined in Section 3.1. The design scores 4.6 out of 5 in this category.

7.7 Conclusion

The author is of the opinion that part of the design being defined as a snapshot of the contemporary condition is the way that passive and active technologies are applied in the building. It is therefore important to note that we find ourselves as humans at a very interesting point in our history where we know that the way we build needs to change but we have become very dependant on the ways of the past.

This design seeks to recognise this fact and combine passive systems that are seen as environmentally friendly with stereotypical existing technology as a way to move forward. Hopefully in the future we can move to new and innovative construction methods that will allow us carbon neutral construction.

What the author thus proposes is that we realise that we are in a process of transition and embrace that, by combining 'green' and 'non-green' design approaches while working towards more energy-efficient design solutions.