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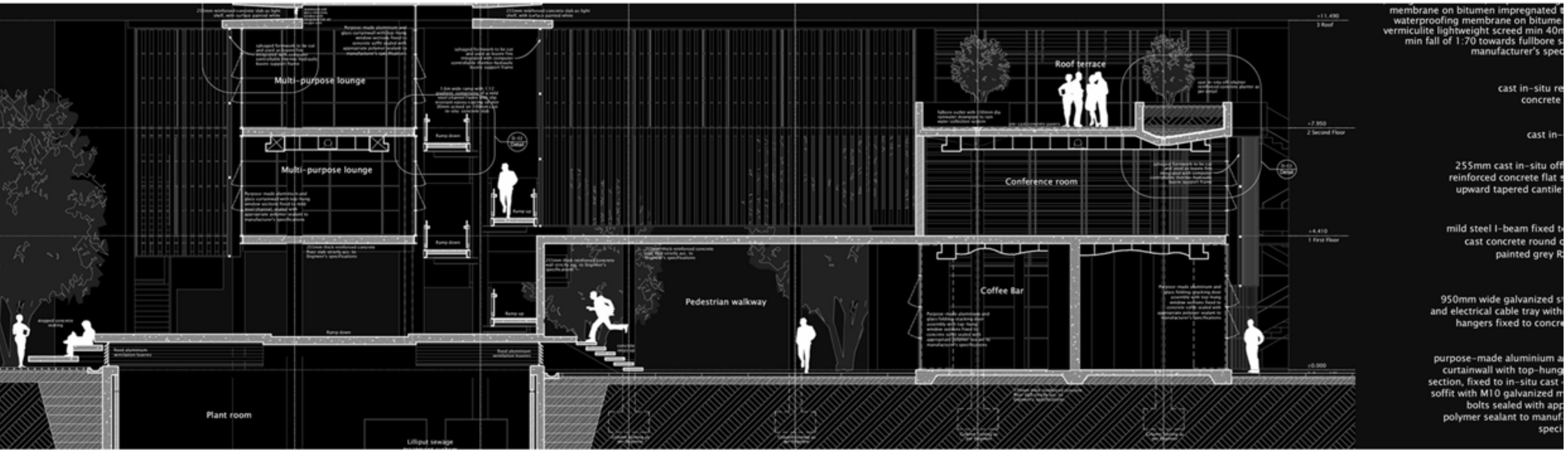

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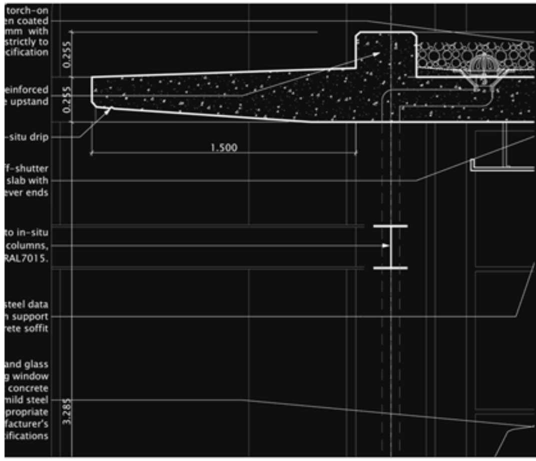



# 05 technical investigation

- sustainable design
- concrete as a building material
- structure - skin - infill envelope
- integrated building systems
- landscape


5.01 A photo collage of various images to illustrate the complex nature of Sustainable Design.

05
technical
investigation

## Sustainable Design

Sustainable design is a movement in contemporary architecture, which among others aims to create environmentally friendly, energy-efficient buildings and developments by effectively managing natural resources. This holistic approach to the design of buildings places a high priority on human health, economic viability, and environmental and resource conservation performance over the building's lifecycle. A baseline study which indicates the performance of the building, is located in the addendum section of this dessertation.

### Principles

• *Connecting with nature*

Whether the design is a building in the inner city or a landscape in a natural setting, connecting with nature brings the designed environment back to life. Effective design helps inform human beings' place within nature.

• *Understanding natural processes*

In a natural system waste does not exist: the by-product of one organism becomes the food for another, therefore creating a closed system. Working within these natural cycles enables the opportunity to engage in processes that regenerate rather than deplete natural resources.

• *Understanding Environmental Impact*

By understanding the impact of the design an informed decision will be made by evaluating the site, embodied energy, toxicity of the materials, and the energy efficiency of the design, materials and construction techniques.

• *Embracing co-creative design processes*

Designers of sustainable environments are finding it important to collaborate with systems consultants, engineers and other experts in the beginning stages of the design processes, rather than at construction phase.

• *Understanding place*

Understanding place helps determine design practices such as solar orientation of a building on the site, preservation of the natural environment, and access to public transportation.

• *Understanding people*

Design must take into consideration the wide range of cultures, races, religions and habits of the users inhabiting the built environment. This requires sensitivity and empathy for the needs of the people and the community.
(Sustainable Architecture and Building Design, 2007, www.arch.hku.hk.)

The challenge now is to find harmony between environmental considerations, economic constraints, and the needs of the community.

## Concrete as a building material

*"Concrete is more than an essential material. It is, in terms of its constituents, and wide-ranging properties and applications, one of the most environmentally friendly of all building materials. In an era of increased emphasis on sustainable development and the environmental impact of construction, concrete has much to offer."*
(Sustainable Design, 2008, www.greenbuilding.co.za.)

Concrete is an environmentally friendly material for building projects and has long been an indispensable component of the economic and social growth of countries. With this construction material's economic versatile qualities it makes concrete the designer's material of choice.
It offers excellent sound and fire protection as well as high thermal mass, and eco-designers believe that "the way to sustainable building lies in the long-life, adaptability, and low-energy design of concrete, because the earth's resources are best conserved if the service life of the building is prolonged, therefore the durability and longevity of concrete makes it an ideal choice."
(Sustainable Design, 2008, www.greenbuilding.co.za.)

5.03
A photo of a concrete surface.

| | Continuous flat slab | | Cantilever slab | |
|---|---|---|---|---|
| | Required | Provided | Required | Provided |
| • Max. span (L) | between 6 -7.5m | between 6-7m | between 2-3m | between 1.6-2.8m |
| | | | | |
| • Min. depth (d) | between L/25 - L/30 | 255mm | L/10 | 255mm |
| | between 200 - 300mm | | between 200 - 300mm | |

Reference: Smit, J.E. 2005. *Simplified structural design*. Pretoria: Univ. of Pretoria.

| | Round column | | Retaining wall | | Concrete wall | |
|---|---|---|---|---|---|---|
| | Required | Provided | Required | Provided | Required | Provided |
| Height | 2-4m | 3-4m | 2-6m | 4.8m | 2-4m | 3-4m |
| Slenderness ratio (h/d) | 6 to 15 | 7 | 10 to 12 | 12 | 18 to 25 | 18 |

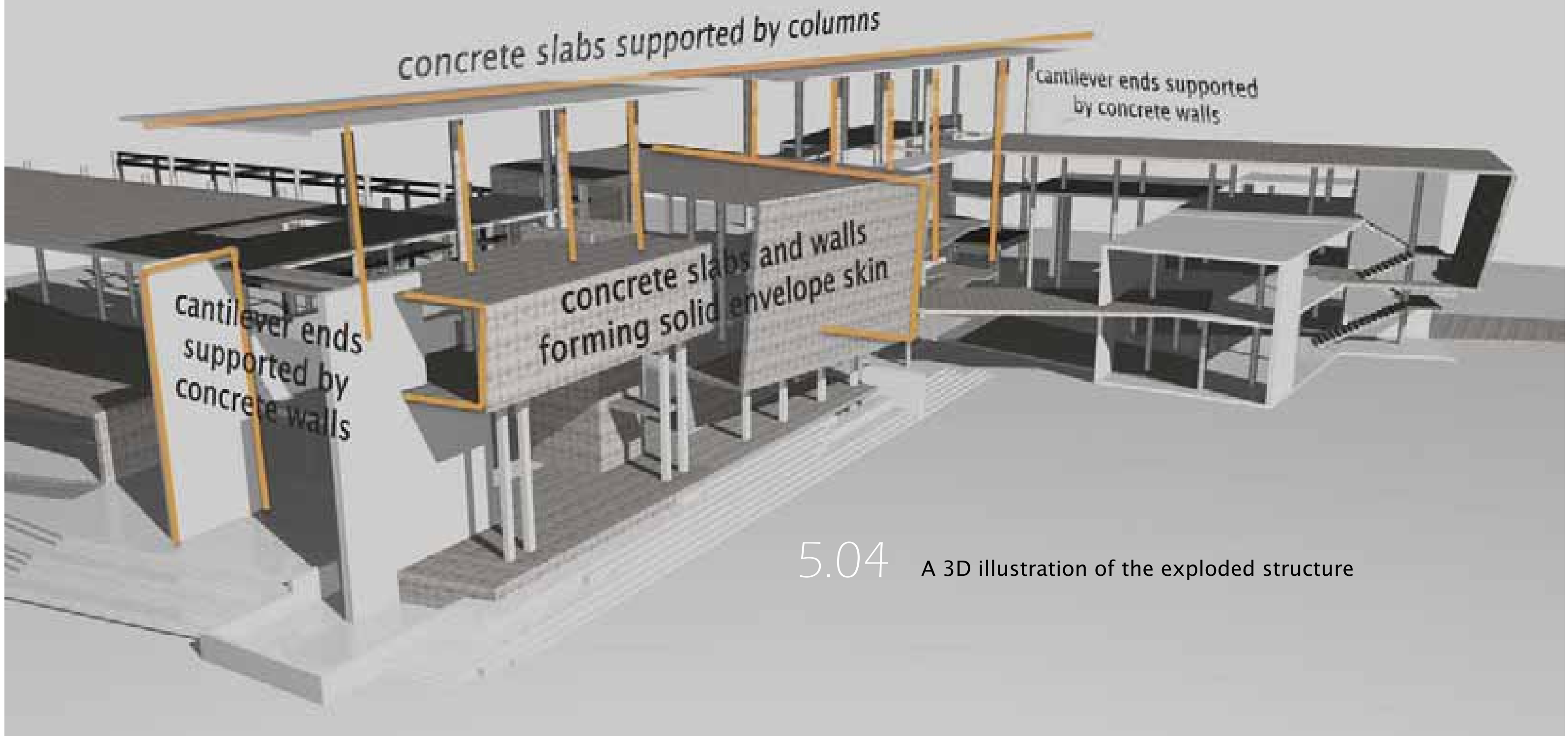
## Structure - Skin - Infill envelope

The structure of the building is designed to act as a kind of 'exoskeleton', therefore the structure becomes 'the skin' of the building. This idea of exposing the structure emphasises the honest architecture of the building and has its roots in the Modern Movement: *"the paradoxical change that the architect, who shortly before had kept the engineer carefully hidden behind the scenes, now chased him out on the stage to entertain the public with his art."* (Ford, 2003: p.57)

The recyclability, durability, energy efficiency and versatility of concrete, makes it an ideal building material for sustainable design. The structure of the building thus comprises out of reinforced concrete elements. Crushed recycled concrete has been re-used as aggregates for the reinforced concrete structure. This decreases the reprocessing of construction materials, thus retaining some of the expended and embodied energy.

### *Roof, floor and column construction*

The reinforced concrete flat slabs are, as indicated with image 5.04, are supported by round reinforced concrete columns, and the flat slab ends are supported by reinforced concrete walls. In order to maximize floor area the structure has to occupy the minimum area. Like modernist architecture, the building's constructional language has a more dramatic demonstration of the play of static forces.
The main North-South orientated building has a roof construction which helps to slow down the flow of stormwater allowing more of the water to evaporate through the foliage. The green roof serves as an insulation layer on top of the concrete slab, and provides UV-protection to the waterproofing membrane.

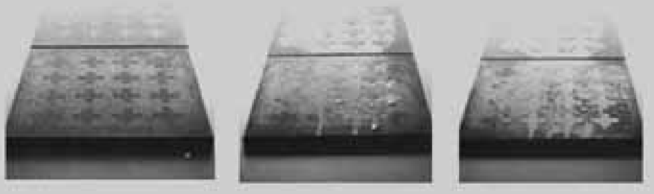



5.04 A 3D illustration of the exploded structure

### *Concrete wall construction*

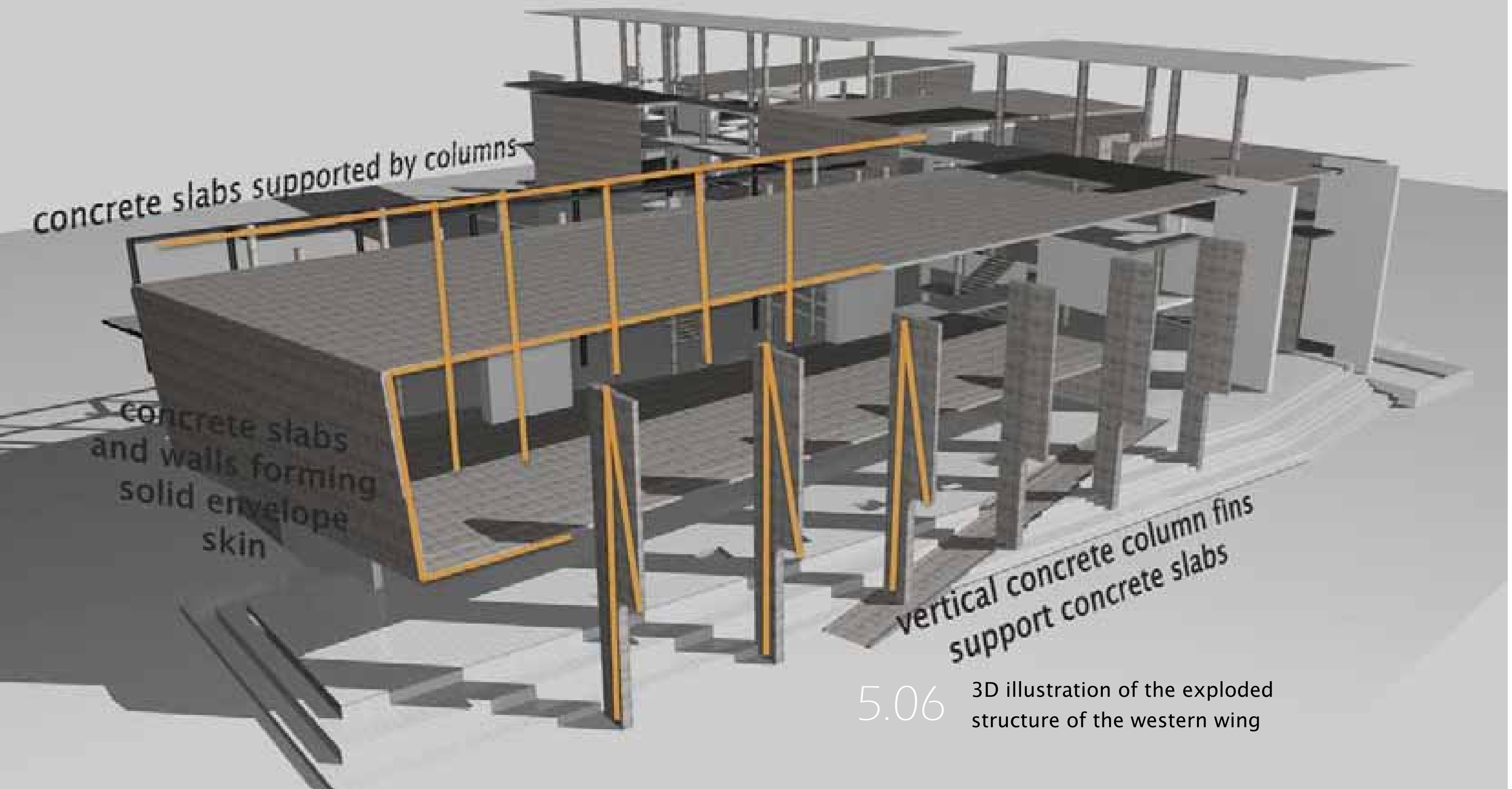
The high performance reinforced concrete used for the wall construction, contains waterproofing and anti-corrosive admixture which provide superior waterproofing to membrane systems.

The vertical reinforced concrete elements of the building are prepared with a non-toxic liquid, silicone-based, transparent dampproofing agent applied to the surfaces as text to form random words and phrases from various world languages. This layer of moisture-sensitive dampproofing reveals the above mentioned text when water is introduced to the surface. With this low-tech technology a dynamic façade is created which responds directly to different weather conditions, producing the desired contrasting light-dark effect as indicated with the images.



5.05 Photos illustrating the effect of water on dampproofing agent on concrete.

The exposed off-shutter concrete and masonry walls reduce the need for additional exterior and interior wall finishes, therefore reducing material use and improving indoor air quality.
The concrete wall brings the roof and the floor together in a unified geometry, linking to the concept of cultural integration with the tectonics of the building.




5.06 3D illustration of the exploded structure of the western wing

### *Curtain wall construction*

The wall has to stand free in front of the columns, which maximizes the structural capacity of concrete by cantilevering the edge of the slab and makes it possible to have a free façade, unhindered by column arrangements.

The vertical glass curtain walls are constructed with partially recycled powder coated aluminium members with fixed and operable double glazed sections. The curtain walls have been designed not to take the operability of the building out of the hands of the user, but rather to encourage users to interaction with the building elements. The thickness of the window assembly is kept to the minimum in order to keep the weight of the curtain wall to the minimum. The curtain walls are fixed to mild steel channel profiles, which are in turn fixed to the concrete structure, giving the façade both technical and aesthetic unity. The floor-to-ceiling height curtain walls provided sufficient lighting conditions for the internal spaces, which mean less use of artificial lighting and a significant saving on utility bills.

The western wing of the building has a large aluminium and glass curtain wall to the south, which enables the internal office and meeting spaces to have sufficient daylighting. This façade has large reinforced concrete vertical fins which support the floor slabs and also provide shading from the early morning and late afternoon summer sun.

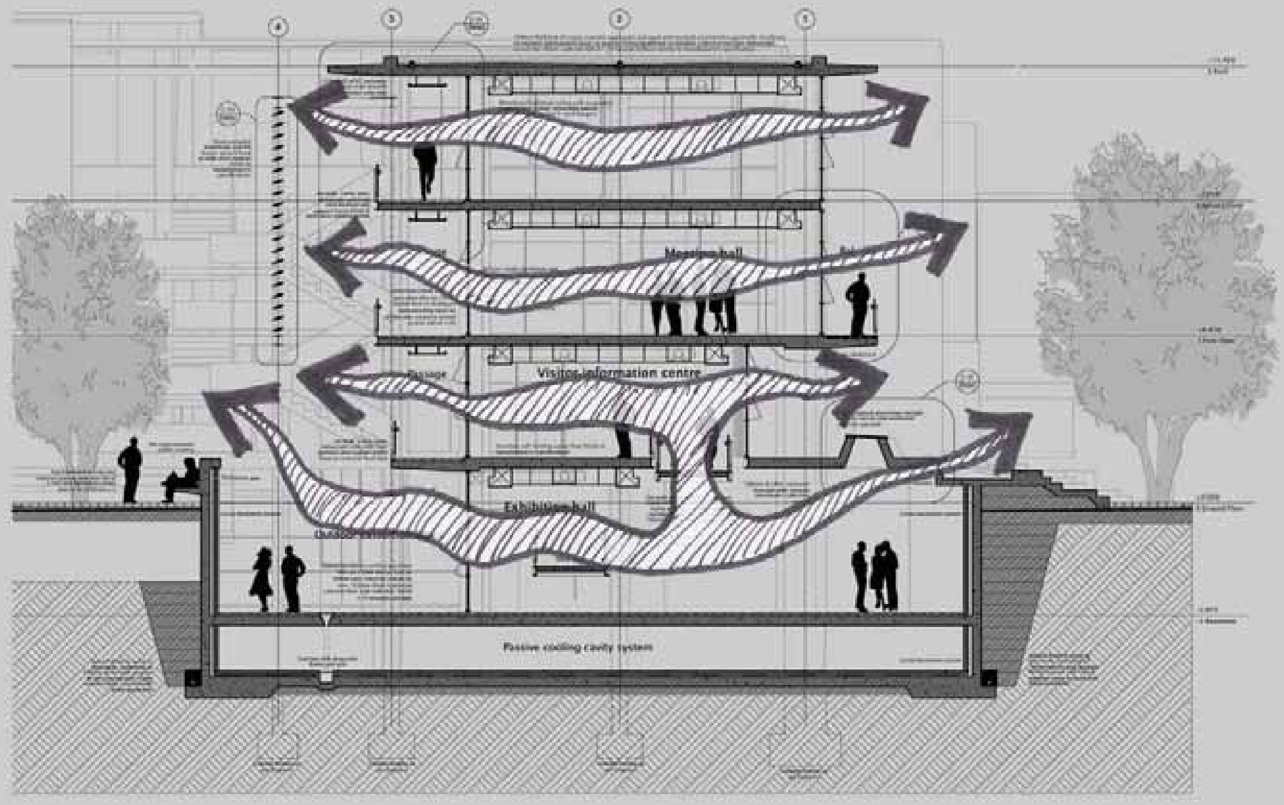

5.07 3D illustration indicationg the curtain wall

## Integrated building systems

In order to comply with sustainable design protocol, the building utilizes a highly innovative system of structural, mechanical and electrical systems integrated to promote environmental sustainability while minimizing operating costs. Heating, cooling, and electricity load reductions are made possible by double glazed curtain wall assembly; double skin concrete wall insulation; concrete roof insulation; efficient lighting; and natural daylighting, allowing for smaller and less expensive HVAC equipment and electrical systems.

### *Air*

The building has been designed so that 94% of the total area of the building has the capability to be naturally ventilated. The image indicates how *natural cross-ventilation* is obtained through the glass curtain walls to the internal spaces. Ventilation is also accomplished using a displacement system.

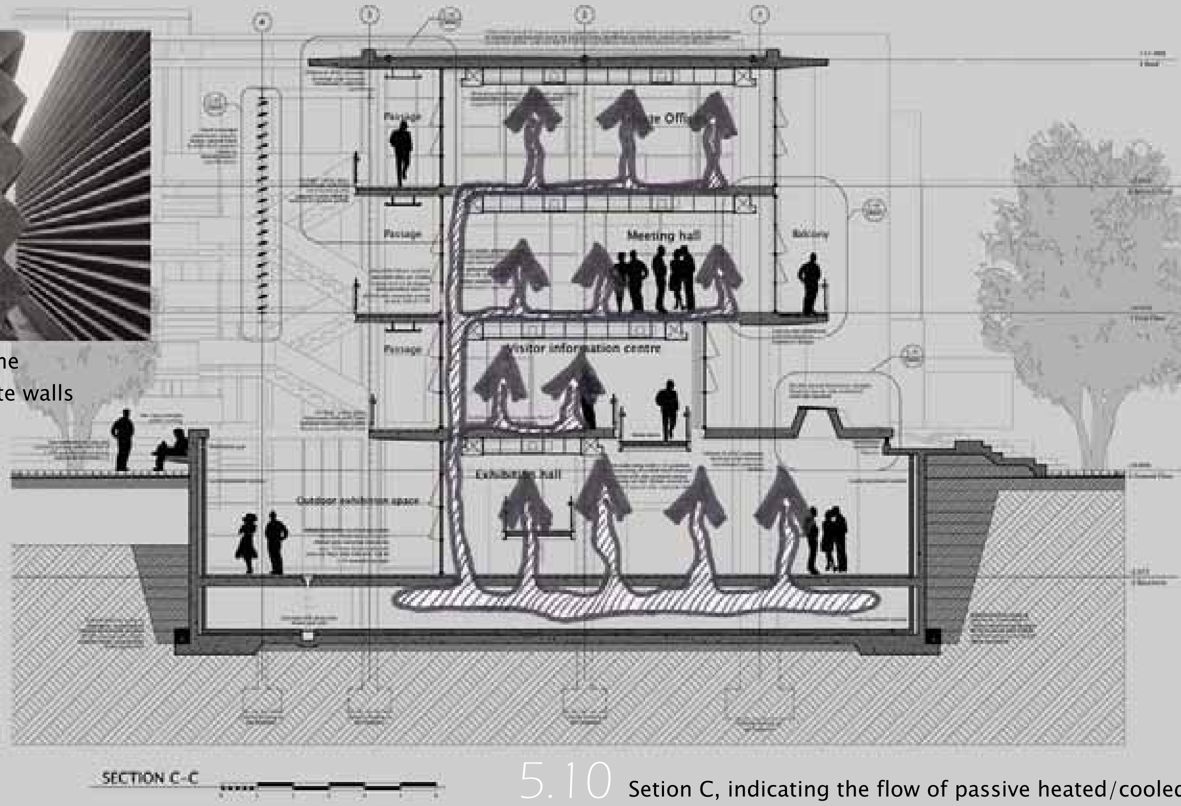



SECTION C-C

5.08 Setion C, indicating the flow of natural cross ventilation

The building has an innovative *passive heating and cooling system* positioned beneath the exhibition hall spanning the entire length of the space. The 100% fresh air intake duct is positioned at the south entrance atrium, where fresh cool air is drawn in through the louvers over the water feature, and down to the air handling plant located in the basement. A maze of corrugated concrete walls (fig.6.xx) is used to provide environmental climate control (cooling and heating) for the western block of the building containing the exhibition hall, information centre, meeting halls and offices. The system comprises of precast concrete walls of 1.2m in height spaced at approximately 1500mm centres, simultaneously providing support for the exhibition hall floor slab. Utilising the specific climatic qualities of Pretoria, with high diurnal temperature variation, cool air is pumped through the maze cavity at night, which in turn cools the concrete walls. During the day, air is again pumped through the cavity, this time being cooled by the concrete. During the winter months the structure's thermal mass maintains an inherent warming potential, which will be supplemented as required. The system directs air to the required spaces, introduced at floor level, dispersed by use of a low-velocity displacement system. As the spaces heat up due to heat gain from occupants and electrical equipment, the air rises, flushing contaminants upward where it is then captured and re-used to supplement the thermo-active slab heating system. In peak summer conditions, the system would be able to reduce the air temperature well below the external ambient temperature, equivalent to conventional air conditioning but using one tenth of the energy consumption and generating less than one tenth of the CO2 emissions.

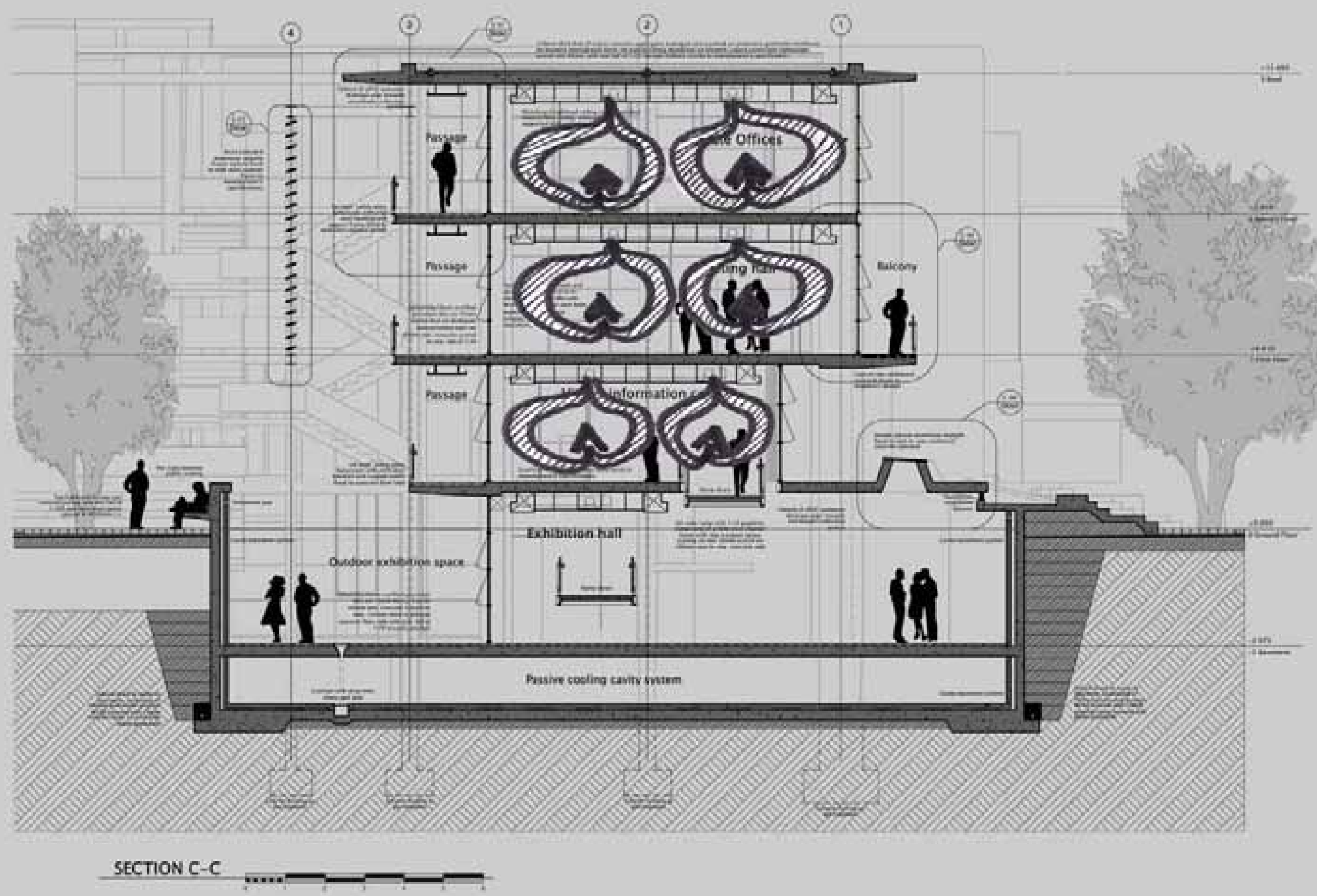

Image indicating the corrugated concrete walls as per Section B.




5.10 Setion C, indicating the flow of passive heated/cooled air.

The passive heating and cooling system is supplemented by a HVAC system, and can also be utilize as a pre-cooling system for the spaces during summer months when the *HVAC system* is at its full capacity, thereby helping to significantly reduce the overall energy consumption on the site. The building comprises of two separate HVAC air handling plants. One is located underneath the events stage servicing the western block and the other is located in the plant room servicing the eastern block of the building. Conditioned air is distributed through flexible horizontal ducts located within the ceiling voids, and vertical concrete ducts between the different floor levels.

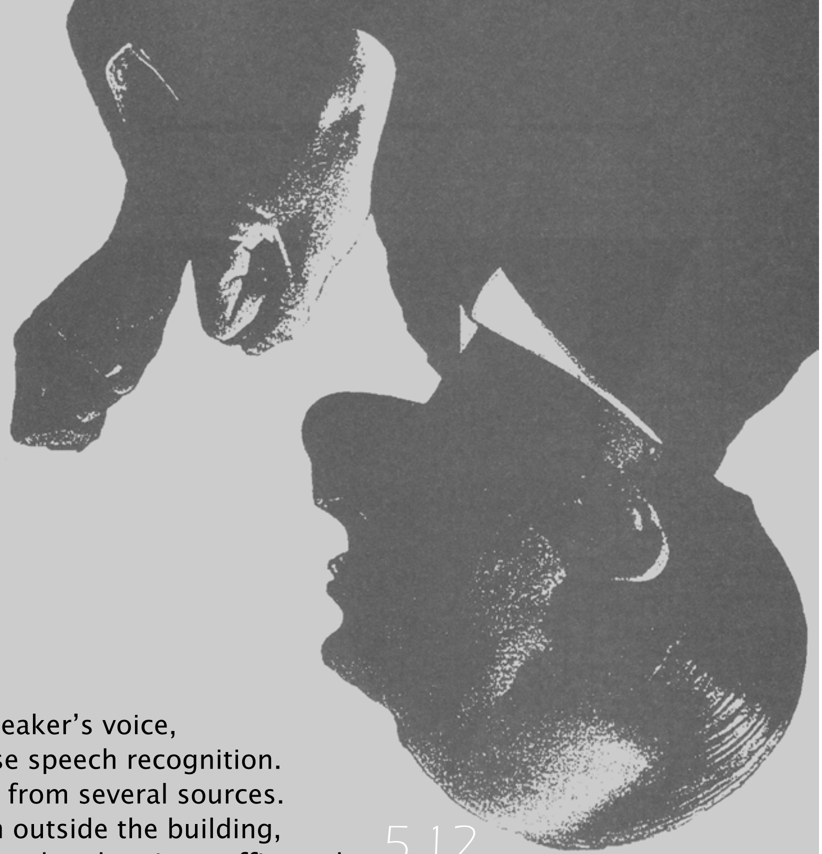
The *thermal mass* of the concrete and masonry structure absorbs the heat created by people, computers, lighting, equipment and solar gain, thereby reducing daytime temperatures and also a reduction of the overall energy consumption.




5.11 Setion C, indicating the flow of air-conditioned air.

## *Sound*

*"For optimal speech recognition to occur in a room, the speaker's voice must be heard clearly above the individual listener's threshold of audibility and the background noise level of the enclosure. The human voice has relatively limited acoustic power. The average sound pressure level that is produced by a speaker (at 1m) during quiet, normal, and loud speech is 45dB, 65dB, and 85dB, respectively."*



5.12 Image of Dadaist John Heartfield. (Fletcher, 2001: p.389)

Valente states that in addition to the power of the speaker's voice, *background noise* in a room may also compromise speech recognition. Background noise according to Valente can originate from several sources. These sources include external noise generated from outside the building, such as airplane traffic, local construction, vehicular and pedestrian traffic; and internal noise that originates from within the building, such as cafeterias, lecture rooms, media rooms, and busy hallways. (Valente, 2000: p.602)

In order to provide the building with acoustically sound functioning spaces, the horizontal surfaces of the building are designed as absorptive surfaces in order to decrease the reverberant characteristics of the hard, smooth concrete interior spaces. The double glazed *curtain wall construction* serves to obstruct background noise from external and internal sources, therefore supplementing the absorptive surfaces for effective acoustic insulation. The *floor surfaces* of interior spaces comprise of a rubber tile flooring system. This flame and slip resistant system is built up of 90% recycled rubber studded floor tiles, with patented interlocking units featuring a unique hidden joining and sealing method. These reusable tiles are easily installed, and can be removed and re-laid in another area where required without the use of toxic adhesives. The thermal, acoustic, and aesthetic characteristics of the product make it an ideal sustainable flooring system. The *ceiling surfaces* of the interior spaces comprise of Gyproc flush plastered RhinoCeiling with removable mineral fibre acoustic ceiling panels, suspended from the concrete soffit with patent T-steel hangers. This composite ceiling system reduces reverberation time and provides the interior spaces with sufficient sound absorption.

5.13 Images of the ceiling panels and rubber floor tiles.

### *Light*

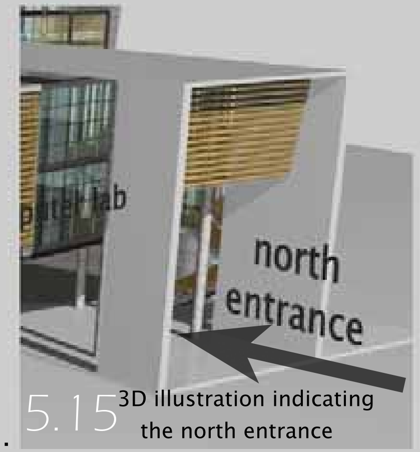
The façades of the building that are exposed to harsh western and eastern sunlight have been designed to accommodate vertical solar shading. Due to the sun angles during the summer months, controllable *solar shading devices* are required in order to protect the internal spaces from excessive solar glare and solar heat gain. Controllable fins, forming part of the *dynamic intelligent building envelope*, are mounted vertically to optimise solar shading and visibility. These fins are controlled by computer software to follow the path of the sun, which reduces the likelihood of 'overshading' or 'undershading' caused by fixed solar shading and will result in the optimum shading angle.

On days when the weather is overcast, light sensors engage the fins to fully open in order to allow the occupants maximum *natural daylight*, reducing the costs of artificial lighting and increasing visibility to the outside at all times. Additional benefits are that, when closed, the fins provide substantial security and can help reduce heat loss during the winter months. The computer software enables the solar system to function in a variety of operating modes including weekend programming, storm shut down and even a cleaning position. A thermo-hydraulic control system is used which is self-powered by the sun using the heat generated to expand or contract fluid within a hydraulic cylinder. This system requires no external power, and detects the position of the sun and forces the hydraulic cylinder to open or close the fins.

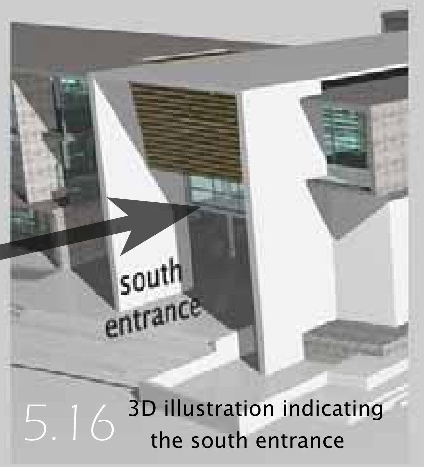
The north-orientated glazed façades of the building have been designed to accommodate horizontal solar shading. Due to the sun angle reaching a maximum of 64.2° during the summer solstice, fixed solar shading devices are required. The fixed fins are mounted horizontally to optimise solar shading and visibility.
The challenge is to maximise daylight entry into the office and meeting spaces whilst protecting these internal spaces from excessive solar glare and minimising solar heat gain. The fins and rafters of the shading systems are manufactured from extruded partially recycled aluminium alloy with brushed stainless steel fixings.


5.14 3D illustration indicating the solar shading devices.

Located respectively in the north and south atriums of the building, are custom-made solar devices manufactured from standard extruded aluminium solar system frame and fitted with re-usable formwork that has been redeployed as louvers. These custom-made *louvre systems* provide shading and glare protection to the atriums. The systems also provide a certain sculptural quality to the high open spaces, and serves as an entrance marker directing pedestrians to the entrance of the building.




5.15 3D illustration indicating the north entrance




5.16 3D illustration indicating the south entrance

## Water

*"Approximately 90% of South Africa has been classified as arid, semi-arid, or sub-humid. 65% of the country receives less than 500mm annual rainfall, generally regarded as the absolute minimum for successful dry land farming. A country in which draught, desertification, and naturally limited water resources are a rapidly growing problem, water conservation has become a necessity."*
(The South African Weather Bureau, 2008.)

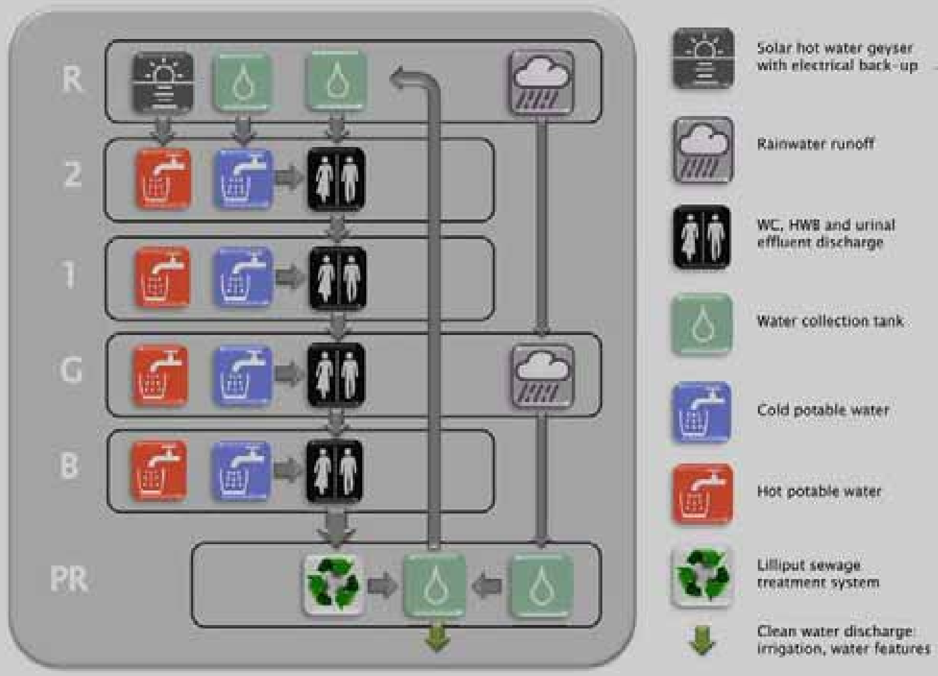
Located in the plant room is the *Lilliput® sewage treatment system*. This compact, versatile and highly efficient sewage treatment plant comprises of an unlimited expansion modular design that has the capability of rendering toxic waste water into 100% reusable water which:

- *Exceeds minimum standards for discharge back into the environment;*
- *Is almost entirely biologically processed, minimizing the need for chemicals;*
- *Is 100% odourless and pathogen free;*
- *Is suitable for a wide range of applications, such as recirculation into irrigation systems, water features, and used for the flushing of water closets.*

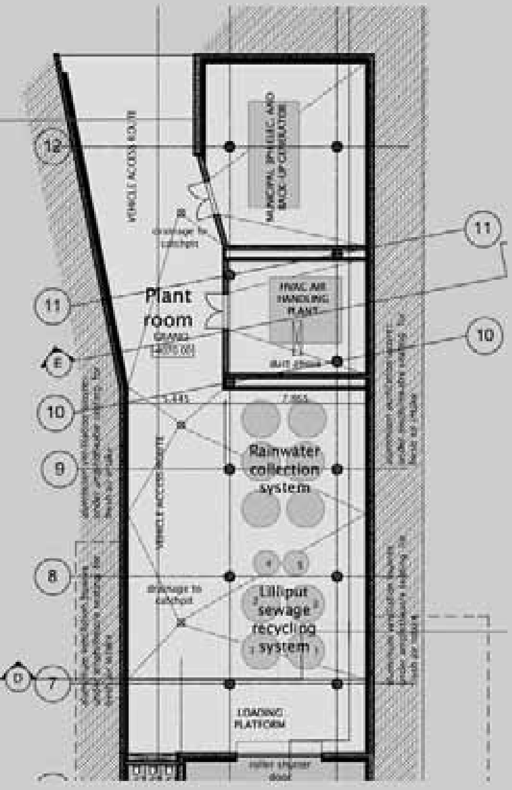
(Lilliput sewage treatment plants, 2007, www.lilliput.co.za.)

The sewage treatment system functions as a circular system within the building. Black and grey water effluent flows from the wet core into the predigestion chambers, then to the balancing, bio-reactor, and clarifier tanks. The last stage is the disinfection tank after which the water is then 100% odourless and pathogen free. Clean water is then available for irrigation purposes and to replenish the water feature. The majority of the clean water is pumped to the roof tanks, where the water is used to fill the cisterns of the building. By implementing the Lilliput water treatment plant water consumption is reduced by approx. 40%, therefore contributing to the conservation of water and energy resources. This contribution to water conservation plays a large role within the urban development framework in which the building functions. Due to the future densification of the precinct proposed by the framework, the demand for water supply will increase by approx. 20% within the next six years. (HCUDF, 2007, www.tshwane.gov.za.)

Located in the plant room is the *stormwater collection system* which consists of six vertical water tanks each with a water capacity of 5500l. The system is connected to various catchment areas located throughout the site. These catchment areas include: the semi-permeable hard surfaces consisting of the urban plaza, the green gathering space, and the green courtyard; and the roof surfaces consisting of terraces, the concrete aggregate roof, and the green roof. The stormwater collection system introduces fresh water into the circular water system which in-turns supplements the roof tanks, where the water is used to fill the cisterns. Potable water is obtained from a municipal water connection, which is pumped to a potable water tank located on the roof. The building utilizes *solar water heating* technology in order to heat the potable water. After the water is used, the grey water is then introduced into the system and the cycle start over again. As mentioned earlier in this chapter, the building contains a thermo-active slab heating system.




5.17 Diagram of the building's wet core indicating the circular water system




5.18 Segment of the basment floorplan indicating the water systems.

During the winter months heating is provided to the exhibition hall (located in the basement) by a *thermo-active slab heating* system. Supplementing the passive climate system, it consists of water piping embedded within the concrete floor structure. Heated water is pumped from the plant room through a network of piping, allowing the floor area to act as a radiant surface heating the interior of the exhibition hall, reducing the overall heating load of the building.

1. PREDIDESTION
2. BALANCING
3. BIO-REACTOR
4. CLARIFIER
5. DISINFECTION

Max. power consumption: 0.9kWh
Avg. power consumption: 0.3kWh
Chlorine consumption
Sodium Hypochlorite @ 0.05mg/l
Calcium Hypochlorite @ 6mg/l
Trichloroisocyanuric acid @ 6mg/l

## Sewage treatment system

### Required effluent capasity

| Accomodation | Population * | Sewage flow * | Effluent |
|---|---|---|---|
| | (Max. no.) | (L/person/day) | max. (L/day) |
| Exhibition hall | 98 | 9 | 882 |
| Urban plaza | 570 | 9 | 5130 |
| Visitor information centre | 13 | 9 | 117 |
| Communication centre | 33 | 9 | 297 |
| Street café | 90 | 20 | 1800 |
| Education theatre | 63 | 9 | 567 |
| Meeting hall | 26 | 9 | 234 |
| Language labs | 32 | 9 | 288 |
| Conference Centre | 24 | 20 | 480 |
| Private offices | 51 | 90 | 4590 |
| | | | |
| Total | | | 14385 |

* Reference: SABS 0400 - 1990

### Lilliput sewage treatment systems **

| MODEL | L/day | L/hour | L/min | L/sec |
|---|---|---|---|---|
| SBC1000 | 1000 | 41.667 | 0.694 | 0.012 |
| SBC2000 | 2000 | 83.333 | 1.389 | 0.023 |
| SBC4000 | 4000 | 166.667 | 2.778 | 0.046 |
| SBC6000 | 6000 | 250 | 4.167 | 0.069 |
| SBC12000 | 12000 | 500 | 8.333 | 0.139 |
| SBC24000 | 24000 | 1000 | 16.667 | 0.278 |
| SBC36000 | 36000 | 1500 | 25 | 0.417 |
| SBC48000 | 48000 | 2000 | 33.333 | 0.556 |
| SBC72000 | 72000 | 3000 | 50 | 0.833 |
| SBC100000 | 100000 | 4166.667 | 69.444 | 1.157 |

| Technical Specification | BLOWERS | | | | TRANSFER PUMP | | DISCHARGE PUMP | | PEAK | AVG |
|---|---|---|---|---|---|---|---|---|---|---|
| MODEL | QTY | WATTS | TOT W | DUTY | WATTS | DUTY | WATTS | DUTY | LOAD (kW) | LOAD (kW) |
| SBC 24000 | 2 | 125 | 250 | 100% | 370 | 60% | 250 | 20% | 0.87 | 0.52 |

** Reference: Information brochure; Lilliput domestic sewage treatment plants. Tel: 011 880 2800

## Rainwater collection system

Annual rainfall of Pretoria: 380-700mm
Average: 540mm

Roof areas:
- Green roof: 370 m²
- Concrete aggregate roof: 1077 m²
- Roof terraces: 195 m²

1642 m²

Semi-permeable hard surface runoff: 3500 m²

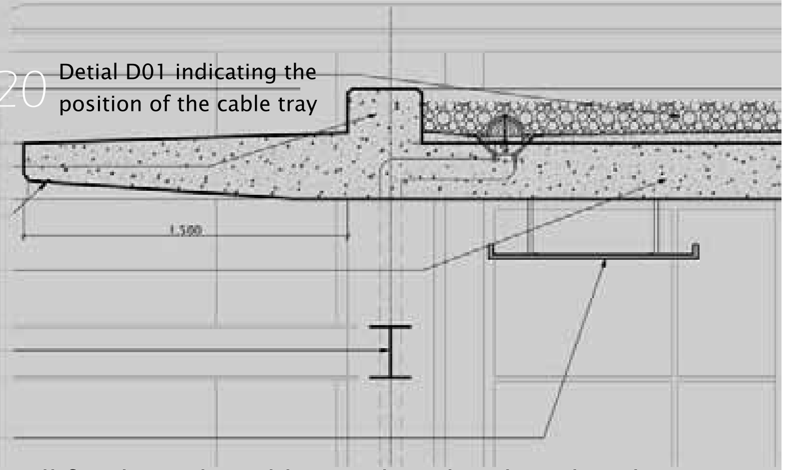
Total 5142 m²

Max. capacity collectable rain water : 2.77mil m³ per annum
7590 m³ per day

Amount of 5500l water tanks required: 2
Amount of 5500l water tanks provided: 6

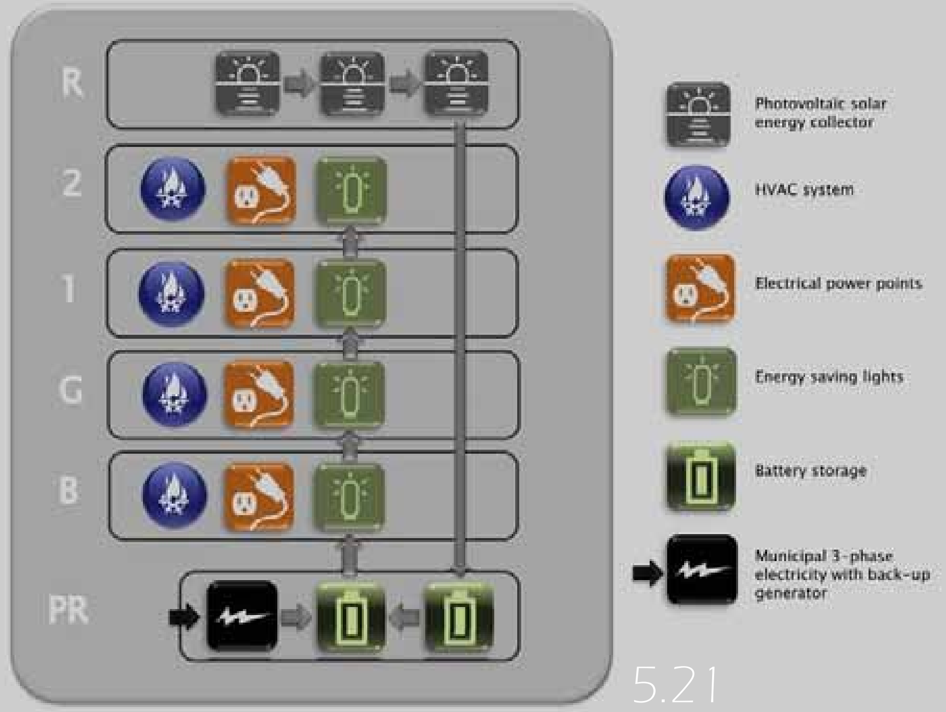
Downpipe size:
100mm²/m² - all rainfall regions
minimum Ø75mm
Calculation: 100 mm² x 33 = 3300 mm² = 57mm
Downpipe diameter required: 57 mm
Downpipe diameter provided : 100 mm

# Data and Electrical system




5.20 Detial D01 indicating the position of the cable tray

Three phase electricity is obtained from the municipality and backup generator located in the plant room. The *data and electrical cabling system* is contained within the 950mm wide exposed galvanized steel cable trays with support hangers fixed to the concrete soffit. These steel cable trays can be moved or adjusted as desired, making the system extremely flexible for when the demand for extra cabling is increased. Therefore the system can be retrofitted at any time of the building's life cycle, without damaging the building's structure or wall finishes. The cabling is then distributed to the different distribution boards located on each floor within the electrical ducts provided. From here the cabling is distributed to power points embedded within the concrete floors, and to various power points within the plinth of the aluminium office partitioning walls. The building utilises *photovoltaics* which are located on the roof and connected to battery storage components located in the plant room. This green energy system supplements the electrical system which operates the *energy saving artificial lighting* of the building during the day and night. The *photovoltaic solar shading system* located in the roof of the south entrance atrium, not only allows shards of sunlight to enter into the atrium space, but also supplements energy to the building, due to its innovative photovoltaic louvre panels.




5.21 Diagram indicating the electrical system

5.22 3D Images of the photovoltaic shading system

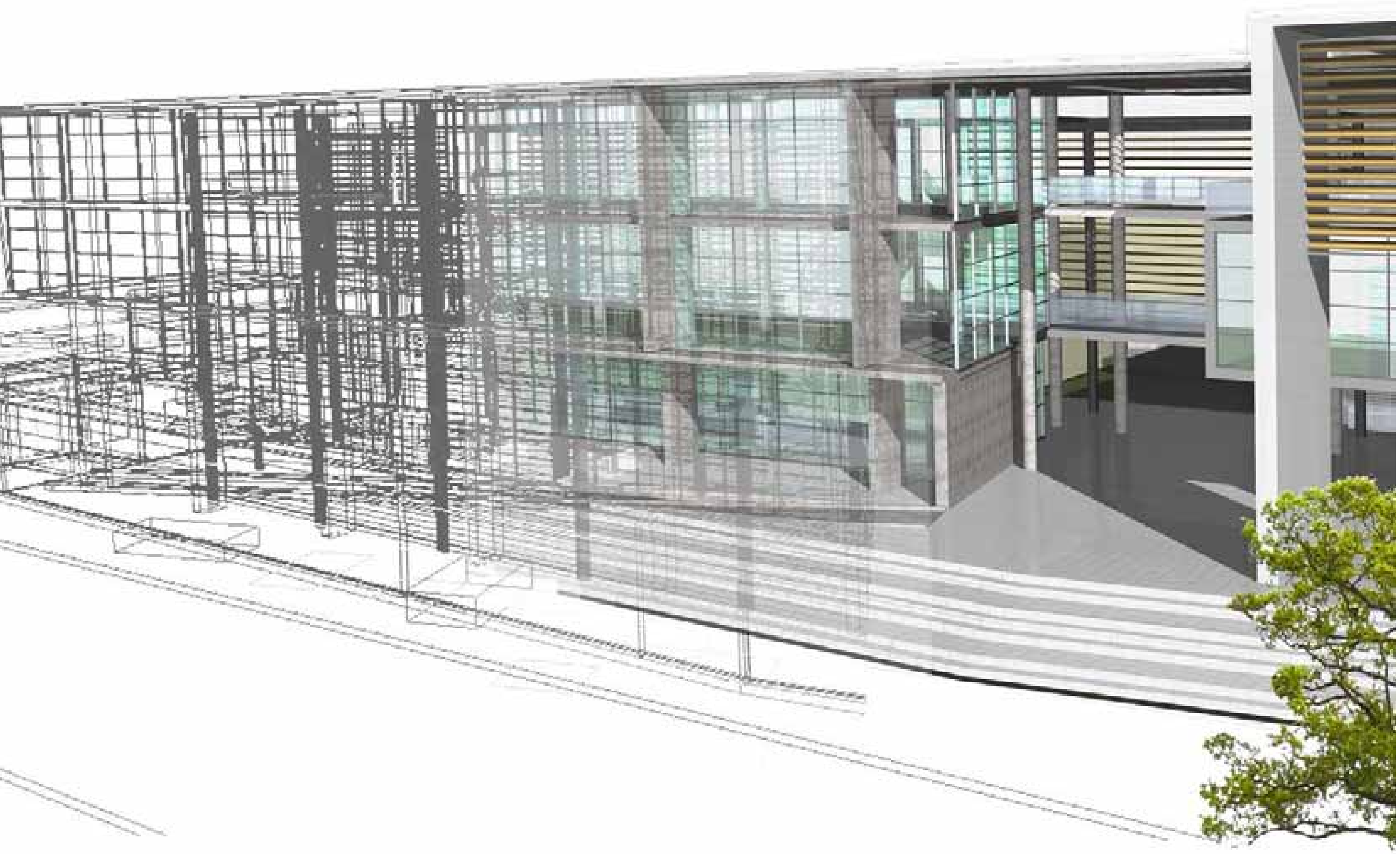
Positioned on the exterior wall of the education theatre, situated on the eastern elevation is the *digital media façade*. The rapid technological development of light emitting diodes (LED) has now cleared the way for the displaying of large-scale media content on building façades. "As a holistic, visionary lighting solution, LED combine high luminosity with longer service life, smaller component size and the possibility of controlling them easily via Internet from any PC. A conventional light bulb produces 3 lm/W; a halogen lamp 20 lm/W; an LED 60 lm/W. So an LED is twenty times more efficient than a light bulb. The smaller the distances between image dots, or pixels, the greater the resolution and the better the image quality. Apart from projection and back-projection – both of them techniques that only work at night, which require the creation of special projection surfaces and the deployment of extremely expensive projectors at precisely determined positions – billboards are the conventional procedure for the 'medialization' of façades."
(ag4 Media Mesh catalogue, 2008, www.mediafacade.com.)

These weather resistant stainless steel wire mesh with interwoven LED profiles provides a permanent, integrated and intelligent 'medialization' of architecture. "The power consumption for the 100m2 media façade will average 3 to 5 kW/h, and maintenance is also simple within the patented construction of the mesh where individual LED profiles or control units can be easily replaced if necessary." (ag4 Media Mesh catalogue, 2008, www.mediafacade.com.)

5.23 3D image indicating the Media facade

5.24 Media facade on the T-Moblie Headquarters in Bonn, Germany.

5.25 LED woven MediaMesh



## Landscape

The surfaces meandering through the urban plaza and around the footprint of the building are constructed with insitu-cast concrete blocks. These blocks are made from concrete aggregates which have been crushed and salvaged from demolished concrete structures and sourced from various construction industries. Utilizing these by-products from the industries enable the reduction of landfill use and embodied energy of concrete. Scattered throughout the landscape are permeable green patches where the earth punches through the hard surfaces. These green patches allow rainwater to filter through, reducing rainwater runoff whilst creating soft relaxing spaces around the building's periphery. Additional indigenous trees are planted in these spaces which include species like Celtis Africana, Acacia xanthophloea, and Vepris lanceolata.
Pre-cast concrete blocks are laid on the tread surfaces of stairs and on the amphitheatre seating surfaces. These surfaces are inscribed with layers of typographically scaled and interwoven texts of various natural languages mimicking the engravings found on the Rosetta stone.

5.26 3D rendering of the urban plaza with concrete surfaces.