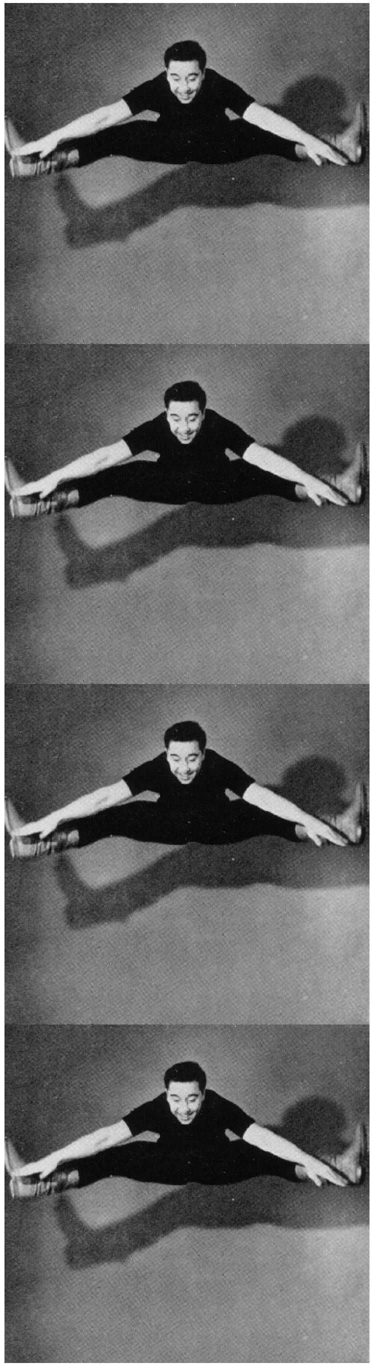
technical report



Passive systems

Good design exploits the potential for passive solar gain by consideration for glazing area, thermal mass and orientation (Baker & Steemers, 2000, 56). The basic idea of passive solar design is to allow daylight, heat, and airflow into a building only when beneficial. The objectives are to control the entrance of sunlight and airflows into the building at appropriate times and to store and distribute heat and cool air so it is available when needed. Many passive solar design options can be achieved at little or no additional cost.

Building orientation and layout

The plan of the building is spread out and irregular in shape which means that the building will be more responsive towards climatic changes and will have good potential for cross-ventilation. The area of envelope per given floor area is relatively large which means that direct and independent ventilation can be provided to various rooms, heightening user control.

The orientation of the building is east-west in order to have the largest facade to the north, which enable the use of passive heating systems during winter, and the smallest facades to the east and especially the west to limit excessive heat gain during summer.

The building's layout enable good natural lighting, with no person being further away than 6m from natural daylight in any of the occupiable rooms.

Facade proportions:

North facade	$=1011m^2$	$=36\%$
East facade	$=514m^2$	$=18\%$
South facade	$=833m^2$	$=29\%$
West facade	$=493m^2$	$=17\%$
Total facade	$=2851m^2$	

Relation between floor area, envelope and volume

	floor area	envelope	volume
Groundfloor	$1258m^2$	$1110\ m^2$	$5724m^3$
First floor	$1269m^2$	$774m^2$	$3807m^3$
Second floor	$1147m^2$	$939m^2$	$3441m^3$
Total	$3674m^2$	$2823m^2$	$12972m^3$

Floor area to envelope ratio

	floor area	:	envelope
Groundfloor	1	:	0.88
First floor	1	:	0.61
Second floor	1	:	0.82
Total	1	:	0.77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performing arts centre & workshops

proposed multi-functional buildings

1 proposed buildings in existing city fabric
2 site model
3 concept model

Windows and glazed facades

Windows and glazed facades provide visual and auditory contact with the outdoors. All of the occupiable rooms have views to the outside in order for occupants to be aware of what is going on outside like changing weather conditions, time of day and outdoor activities. This is psychologically important for people. It was necessary to completely shut out the outdoor environment to avoid daylight and noise in the auditorium and two theatres.

The other important factor that came into play whilst designing windows and facades were energy considerations. The size and orientation of these two elements determines heat gain, heat loss and quality and quantity of natural interior lighting.

The most glazing occurs on the north and south facades. Thr ough the use of solar shading on the north facade, direct radiation is kept out during the summer but allowed through the glazed facade during winter. In deciding on double or single glazing on the north facade a few factors were taken into consideration:

Comparison between single and double glazing

Factor	Single	Double
Heat loss	high	low
Heat gain	high	low
Acoustic insulation	low	high
Cost	low	high


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After considering all the above it was decided that the most important function off the north facade was to allow heat gain during winter, because of this single glazing is used. Double glazing is used on the south facade because this is where most of the heat loss will occur during winter. The air cavity between the two panes reduces the heat transfer coefficient (U value) of the glass, thus reducing heat flow by convection through the glazing. Here it was also important to strike a balance between solid and glazed facade in order to limit heat loss during the winter but still keep the facade animated to draw people in from the street.

From a acoustical point of view it was possible to use single glazing on the north facade because it faces the existing Lutheran Church, but the south facade which forms the edge of a pedestrian movement spine needed acoustic insulation, which is partly provided by the double glazing.

The solar shading on the north facade in fixed timber louvers, stained dark brown to restrict reflected solar radiation during the summer months.

When designing the eastern and western facades the character was devised from considering daily solar patterns opposed to seasonal patterns, as was the case when designing the northern and southern facades. The southern facade is protected against direct solar radiation by 50 x 50 timber battens in order to provide contact with the exterior as well as opportunity for natural ventilation. The western facade is kept solid, except for where physical interaction between exterior and interior as well as vertical interaction is needed in the outdoor social space. Protection against direct solar radiation is provided by external sliding timber screens.

1 precast concrete elements fixed to steel H-profile column
2 south facade
3 detail model of north facade


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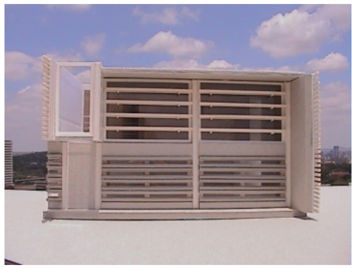
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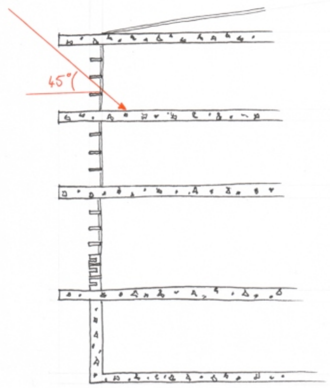
Heating

Because the building will be used during the evening heating two different forms of heating is introduced. Firstly heating during the day, this form of heat is provided through direct solar radiation and heated air, and secondly heat during the evening, which is provided through storing heat in thermal mass materials.

Solar rooms

All the rooms facing the north, with exception of the library and exhibition space, will be heated through admitting direct solar radiation. On groundfloor level, where the library and exhibition space is located, the envelope consists of a pre-cast concrete wall with 150 high strip glazing where the wall will be used as thermal storage element. This is done for mainly two reasons, firstly because direct sunlight is undesired in both cases, and secondly because the library will be used extensively during the evening, which means that the time lapse for heat release is necessary. Short wave solar radiation falls on surfaces in the rooms that absorb this energy. As the surfaces heats up, some of the energy is immediately re-radiated as long wave infrared radiation and the rest of the energy will be released after a certain time lapse. The amount of heat storage depends on the thermal mass and its colour. Concrete floor slabs finished with slate tiles, and to a lesser extent the internal partitions will be used as thermal storage elements, storing excess solar energy during the day and releasing it during the night.

North facade development:



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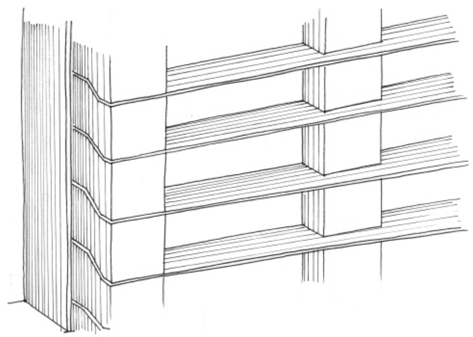

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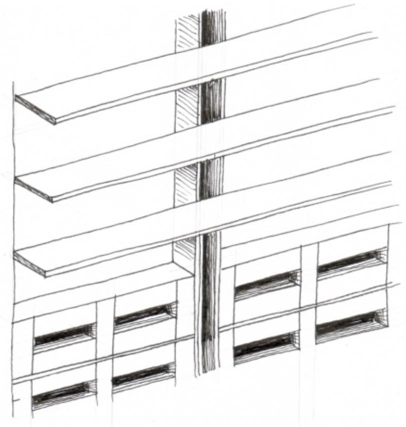
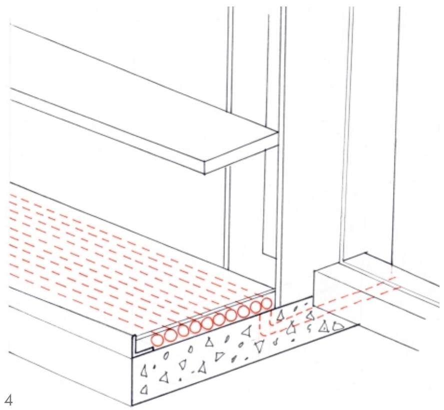


Non-solar rooms

Nighttime heating

To heat the non-solar rooms during the evening a low temperature radiant system, meaning that a surface temperature that is comfortable to touch must be created, is used. Water will be heated on the north facade, in a network of PVC pipes covered with glass on a steel sub-structure, by solar radiation and then be circulated through the pipes. Some of the heat energy will then be transferred from the water into the floor slab and after a time lapse energy from the concrete and water will be released into the room.



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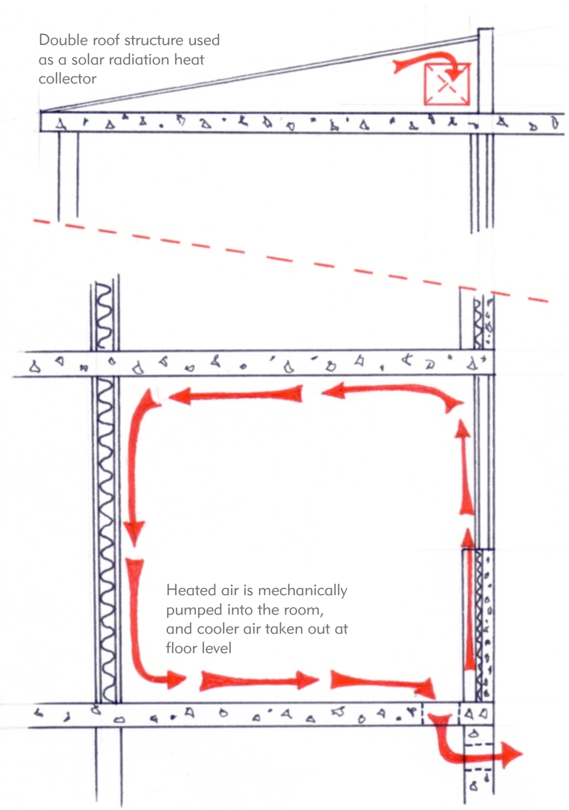
1 section through facade
2 precast concrete elements
3 timber shading, fixed to H-profile columns
4 section through water heating system

Daytime heating
The acoustic insulated drywall system used on the first and second floor will act as a thermal barrier, which make it impossible to introduce thermal coupling between solar and non-solar rooms. A convective heat emitter, using warm air, will be used because a quick response is needed during the day. The roof on the north side of the building is a double structure, to form a solar radiation heat collector. It consists of a 150 reinforced concrete slab, with a steel sub-structure and IBR sheeting. The air inside this cavity will heat up and travel to the highest point in the cavity from where it will be mechanically pumped through ducts into the south facade, which is a cavity wall. The wall will consist of 80 pre-cast woodcrete panels, which have a higher thermal insulation value than concrete, 60 extruded polystyrene panels and a 60 air cavity. All the mechanical fans will be directly connected to solar panels on the roof so that grid electricity will only be used as a back-up system. The heated air will be released next to the inner layer of glazing to counteract the natural process of air cooling and sinking down the glazing. The process of exchange ventilation, where stale air is taken out at the top of the room, will be changed so that cold air, which in this case will be a mixture of fresh and stale air, is taken out close to floor level. In summer this process will be reversed so that cool air from the outside is taken in at floor lever and is extracted at a higher level.

The most influential element in both the above-mentioned cases is the south facade, which is well insulated, in order to minimise heat loss.



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Natural ventilation

It appears that in many cases occupants are much happier and healthier in naturally ventilated buildings, in spite of the variability of environmental conditions which results (Baker et. al., 2000, 52). Two ways of generating natural ventilation is used, namely wind pressure and thermal buoyancy.

Wind pressure
The building is irregular in plan, which means that there is an opportunity to introduce cross ventilation. When wind blows up against the building there will be positive pressure on the windward side and negative pressure on the leeward side. Because openings are distributed over all the facades of the building it is ensured that, no matter what the wind direction is, openings will be at different pressures that will introduce a natural airflow through the building.


2

1 convective heat system
2 detail model of ventilation Stack

Thermal buoyancy

Thermal buoyancy generates a vertical pressure difference which is dependant upon the average temperature difference between the column of warm air and the external temperature, and the height of the column of warm air (Baker & Steemers, 2000, 56).

To suffice to the above mentioned criteria in order to create thermal buoyancy two solar chimneys is used. In order to increase the height of the column of warm air the solar chimneys is 3000 higher than roof level and protrude 2100 through the first floor slab. This offers the opportunity to have a part of the solar chimney exposed to direct solar radiation so that a temperature difference is created. The east facade of the stack will be off-shutter concrete and the west facade will be clad with black slate tiles, so that the temperature difference is even greater in the afternoon when ventilation is needed the most. To ensure that the stack effect gets started extraction fans will be fitted at the top of the chimneys. These fans will be directly connected to a solar panel, located on the roof. During the summer months air will be pulled in from the south side of the building, where the air will be cool because this area will be in shade throughout the day. During the winter months air will be pulled in from the north side where hard finishes, such as concrete and slate tiles, will be heated by direct solar radiation.

The main vertical circulation area will be ventilated through the use of supply and extract ventilation, driven by wind pressure and thermal buoyancy.

Day lighting

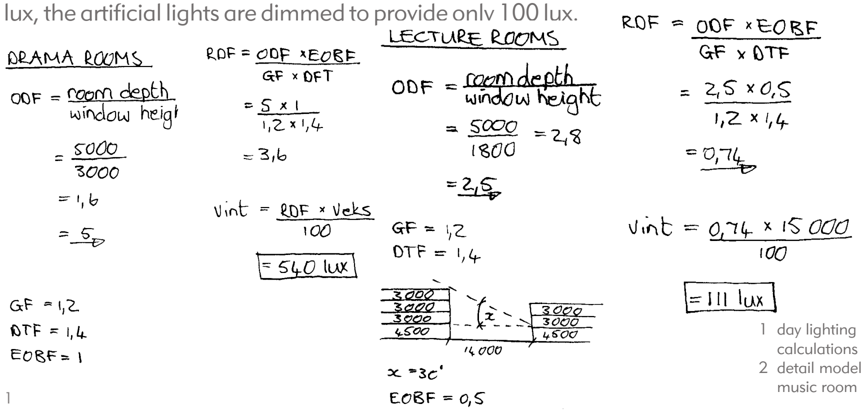
Daylight is desired not only for energy conservation but is usually considered superior (psychologically) to electric lighting (Givoni, 1998; 53).

Daylighting can save energy by displaying the electrical energy that would otherwise be used to provide artificial lighting. In most non-domestic buildings this is potentially the most significant energy-saving measure (Baker &Steemers, 2000; 42).

Because artificial lighting rarely contributes to over luminance, people rarely switch off lights when the daylight luminance is adequate. To save on energy an automatic lighting system which detects daylight illuminance levels is used. The system will switch off lights if the daylight illuminance is above the needed level, light may be switched on manually and will also be switched off when a nil occupancy is detected by an occupancy detector.

Day lighting requirements for lecture rooms are 70lux (Van Rensburg, 2001; 8). Daylight is defined as light under overcast conditions, which means that direct radiation is ignored in the calculations. For this reason the external shading device on the north is not taken into consideration, although it will have an effect on the internal illuminance. Day lighting levels of 540lux is achieved in the drama rooms, and 111lux in the lecture theatres.

Dimming controls are also introduced into the system. For instance when 300 lux is required but the daylight illuminance is only 200 lux, the artificial lights are dimmed to provide only 100 lux.



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1 day lighting calculations
2 detail model of music room

Materials

In aiming towards sustainability the embodied energy of materials is very important. Factors influencing this are the actual sourcing of the material, renewability and recyclability or reusability. Using locally available materials will assist in saving cost and energy and less transportation will result in less pollution.

Timber

Timber resources are renewable.

Recycling

The biggest advantage when using timber is the relatively easy recyclablility and reusability. Prefabricated components, such as battens and planks for external shading devices and internal screens, tongue and groove floor planks, standard timber board products and shiplap siding planks for external cladding, is used throughout the building. If the lifespan of the components exceeds that of the building, it will be possible to reuse it directly.

Wooden floors

The floors in the dance studios will be sprung wooden floors. *Wooden floors give good warmth and sound insulation. They are relatively soft, warm, physically comfortable and do not became electrostatically charged if not treated with varnish* (Berge, 1992; 349). The batten flooring system will be used. Tongue and groove boards are locked into position by hardwood battens. This means that individual floorboards can easily be changed and reused.

External cladding

According to Berge in the Ecology of Building Materials, Pine will last between 40 and 85 years when used unsheltered on the exterior of as building, if not in contact with the earth (Berge, 1992; 172).

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1&2 detail section model of dance studio facade

Panelling for external walls should preferably be of high quality timber with no signs of rot. The planks should be sorted on site and the best ones placed on the most exposed facades of the building. External cladding should be nailed at an upward angle to avoid water seeping in and staying there (Berge, 1992; 345). The condition of external cladding is seldom good enough to be reused, so the treatment used is important so that it can be burned or used as compost. In this case the timber will be treated with beeswax or linseed oil.

Insulation

Timber has many good climatic properties both in its natural form and when reduced to fine particles (Berge, 1992; 279). Compressed wood shavings will be used as loose fill insulation between the concrete skin of the auditorium and the shiplap siding. Even though wood shavings are usually seen as waste, it is possible to re-use it, either by sucking it out and compressing it in another situation, as an energy source through burning or it can be made into compost.

Metal

Steel is used, with reinforced concrete, as the main structural material in this building. Good properties of steel are that it is completely recyclable. In this case standard steel sections are used as far as possible. Prefabricated steel components will be mechanically assembled on site, this increases to opportunity for reuse when compared to welding.

Concrete

Concrete is produced from cement, aggregate, water and in some cases additives. The embodied energy of concrete is relatively high because of the large amount of energy used to produce cement. Lime cement is slightly weaker than Portland cement but because Portland cement with fly-ash releases soluble sulphurs into the environment it should be used as little as possible. The most important factors taken into account when concrete was chosen are embodied energy, compressive strength, fire resistance and heat capacity.

Steel used to reinforce the concrete should be recycled with 10 percent new steel added to increase the strength. Durability of reinforced concrete depend on the quality of workmanship and raw materials, as well as the proportions of the mix and thee location of the building. *Carbon dioxide and sulphur dioxide, both of which occur in high concentrations around industrial areas and towns, are particularly damaging. It has been proved that carbon dioxide can carbonize up to 40 mm into concrete. The concrete loses its alkaline properties as a result and can be subject to corrosive attack* (Berge,1992; 197). To prolong the lifespan of the concrete all reinforcement should have at least 40 mm coverage and construction detailing is done to minimise the time water takes to move off the surface.

The only way to recycle in-situ concrete is to crush it for use as aggregate and fill. Where concrete is not used for structural purposes but only for its thermal storage capacity, prefabricated elements are used. These elements are mechanically fixed to steel H-profile columns to make dismantling possible.

Prefabricated concrete with light aggregate

On the south façade prefabricated concrete panels that contains the highest possible proportion of wood shavings, for thermal and sound insulation, is used. It is also mechanically fixed to steel H-profile columns. The wood shaving will not rot because of the high PH of the cement.

Gypsum board

Acoustic gypsum boards with a woven fibreglass and cardboard cover, glued with potato paste, are used in the drywall system. If gypsum sourced as a by-product from power stations is used the waste situation is improved. The cardboard cover is produced from a

Structure

First a lightweight structure was considered because of attributes such as fast construction and the properties such as recyclability of materials like timber and steel. The main problem that this posed was that a lightweight structure reacts too much to temperature swings and that there is no thermal mass to store excess heat and coolth for later use. After this the idea was to use steel columns, timber beams and concrete floor slabs. Because of the large difference in Young's modulus of the timber and concrete, it will mean that the concrete slab will deflect more than is permitted before the timber beam will support and stop the deflection.

The structure that complied with most of the criteria set in the baseline document is a beneath surface structure of 350 thick load bearing concrete walls in the basement, to be able to withstand the soil pressure, and 500 x 200 reinforced concrete columns. The load bearing walls run through to roof level, with a steel H-profile column and I-beam structure with concrete floor slabs to provide mass for thermal storage. Where the load from the H-profile columns is eccentric, 500 deep reinforced concrete beams will span between the concrete columns and the load-bearing wall in the basement.

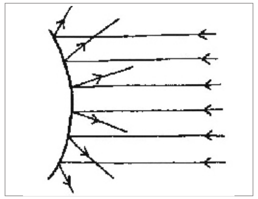
The structural challenge in the building was the auditorium and dance studios. The auditorium cantilever 6m over the sidewalk, to make this possible it will be cast as a solid shell concrete structure, with 200 off shutter walls, 250 roof and floor slab and 250 ribs @ 4500 centers. This structure is supported on a 350 load bearing concrete wall and 230 x 500 concrete columns from the basement.

The dance studios only cantilever 3,4m and is constructed in the same manner as the auditorium, except that steel H-profile columns are used so that the facade can be opened up.

Acoustics

Recommended sound levels:

Room	dB
Living area	30-40
Bedrooms	25-30
Foyer	45-55
Lecture theatres	30-35
Music rooms	30-35
Drama room	30-35
Library	40-45
Exhibition space	40-45
Kitchens	45-50
Restaurant	40-50
Conference room	30-35
Private offices	35-40
Open plan offices	40-45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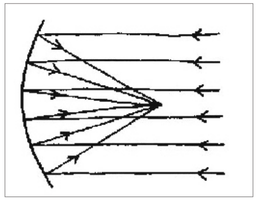
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1 convex surface - diffuse sound
2 concave surface - focus sound
3 auditorium - facing Skinner Street
4 absorption vs. frequency graph
- helmholtz resonator
5 panel absorber
6 dissipative absorber
7 section through auditorium wall
8 composition of acoustic drywall

Theatres and auditorium

The auditorium faces Skinner Street, which means that external noise is a large factor. The auditorium will be constructed as a solid concrete shell. From the exterior to the interior it will consist of 50 timber shiplap siding, 100 loose particle insulation material, 200 concrete wall and a 40 mineral wool fiber board under open spaced timber battens.

On the sides, next to the chairs, convex acoustic panels will be used to reflect the diffused sound back to the audience. At the back of each of these panels will be timber slats to absorb sound.

At the back of the auditorium, where there is no audience seated, there is no need to reflect the sound so timber battens openly spaced over a low density mineral fiber board, with a 100 air cavity, is used to absorb the sound. The mass of air between the slats reacts with the springiness of air in the cavity to form a resonant system, again comparable to the Helmholtz resonator. The mineral fiber board usually introduced behind the slits acts as resistance, broadening the peak of absorption (Everest, 1973; 102). This is a form of dissipative absorber which works on the principle that sound energy penetrates a perforated surface, which in this case is the timber battens, and enters small passages and air-filled cavities in the material. Kinetic energy in the sound wave is then transferred to the material and sets fibers and particles into vibration. Due to the friction the energy ends up as heat. The material needed for this process must consist of elastic particles or thin fibers connected by small air cavities, to comply with this low density mineral fiber boards are used. Compared to other forms of absorbers this particular type is effective over a relatively wide frequency range.

The ceiling consists of suspended acoustic panels, which are partly concave and partly convex shaped. The concave part will focus sound back to the audience. The radius of the curvature should be determined so that the focus point of the reflected sound are lower than the audience so that sound is absorbed by them and the seats before the focus point is reached. The convex part will diffuse and reflect sound in behind the adjacent panel, where it will be absorbed.

Soft seating and a carpet floor finish will be used for absorption in the auditorium and theatres. In the theatres the audience won't be further than 10m from the stage, so there is no need for sound reflection. The same absorption system used at the back of the auditorium will be used throughout the theatres.

Drama rooms, music rooms and lecture theatres

The drama rooms and lecture theatres will acoustically be treated the same. Firstly none of the opposing walls are parallel to avoid successive reflections hitting the same spots each time, which will at least diffuse high frequency sound. In each of the drama rooms one wall will be convex. Three things can happen to sound falling on such a cylindrical surface; the sound can be reflected and thereby dispersed, the sound can be absorbed, or the sound can be reradiated (Everest, 1973; 71). These elements will also act as low-frequency absorbers. The internal walls will be a drywall system using independent tracks and studs for each side of the wall, so that the structure doesn't a form a sound bridge. Furthermore it will consist of a gypsum board face layer with soft board glued to that, with a mineral wool blanked and IBR profile inside. The soft board will dampen vibration in the gypsum board, the mineral wool blanket will absorb sound and the IBR will reflect sound in different directions, diffusing it. The small strip windows which is used to bring natural light into the corridor on the first floor consists of double glazing with a 100 air cavity in between. A suspended 30 mineral fibre suspended ceiling is used with a 110 air cavity above it, in order to act as a dissipative absorber.

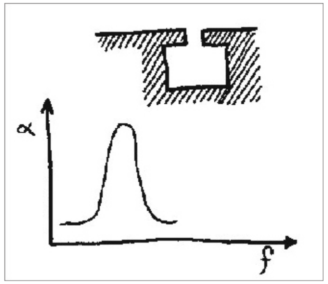
The music rooms will acoustically be treated the same with the exception of not having any windows to the corridor, and it will have a carpet floor finish for more absorption.

Lecture rooms

The same internal drywall system as for the drama and music rooms will be used to control noise from the corridor. The south façade consist of 80 pre-cast woodcrete elements, 60 extruded polystyrene panels and double-glazing for thermal insulation. This system will also act as acoustic insulation, which is necessary because of the public activities on the south side of the building.

Solar chimneys

Because these elements is located in the library and forms the edges of the drama and music rooms the sound generated by the moving air is dealt with in the following way: a 80 mineral wool blanket between the off shutter concrete and a perforated IBR profile. The mineral wool blanket is used to absorb sounds and the IBR profile to reflect and diffuse sound.



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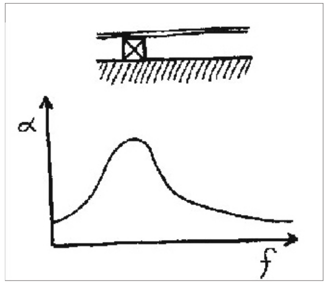

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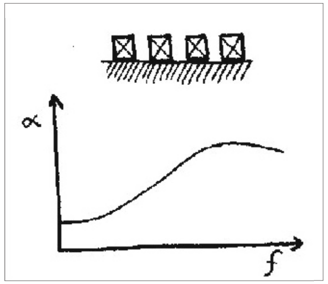

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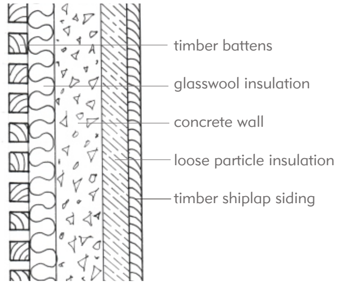

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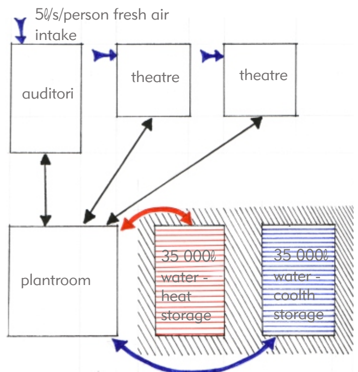
gypsum board
soft board
glasswool
IBR profile
steel stud

Air-conditioning

The two theatres in the basement and the auditorium need to be air-conditioned because of acoustic requirements. The plantroom is located in the basement, with two 35 000 liter water storage tanks sunk into the soil. Instead of releasing the extracted heat or coolth into the atmosphere it is stored in the water. When the spaces are cooled, coolth from the water is used and when the process is reversed to warm the spaces heat stored in the water is used, which means that less energy is needed to either warm or cool the air. The soil around the water tanks will act as insulation so that as little as possible of the heat or coolth is lost. This system is used because air-conditioning in this case can't be viewed seasonally because of the large heat load from the audience, for instance in winter it might be necessary to heat the space to achieve the desired temperature before the audience enters, and then cooling might be necessary to keep the temperature constant.

To provide enough fresh air, as stipulated in the SABS, for 210 persons 0,9m² of duct is needed in the auditorium. To comply with this twelve 300 x 250 ducts, installed behind the acoustic screens, is used. Conditioned air will be introduced close to floor level and extracted at the top of the room. Air exchange will be done on the roof, where air will generally be the cleanest. Because the theatres in the basement are sunk into the soil and them as well as the auditorium is well insulated it will be very little affected by temperature swings, which will mean that less air-conditioning will be needed as opposed to uninsulated rooms.



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1 air conditioning system
2 view to the auditorium from the south

Building management system

Effective controls are essential to obtain the best possible performance from low-energy design features. The low-energy building may in fact require a more sophisticated control regime than a conventional highly serviced building which makes less use of ambient conditions for 'free' heat or ventilation potential (Baker & Steemers, 2000, 89).

An automatic Building Energy Management System (BEMS) will be used, but with manual override capability in order to make occupant control possible. The most important things that will be controlled by the BEMS are heating, cooling, ventilation, HVAC and lighting.

Points that should be taken into consideration when the BEMS is set up:

- target temperatures that is dependent on the type of activity
- spaces with different uses should be in separate zones, as well as spaces behind differently orientated facades
- optimum start controls to adjust warm-up or cool down periods for intermittently occupied spaces, such as the auditorium an theatres, according to ambient temperatures
- lighting in differently zoned areas
- dimmers to adapt artificial light as natural light levels increases or decreases
- occupancy detecting switches for when the building is lightly occupied

The use of manual controls, such as opening windows, will have a large effect on the energy use. Therefore it is important that occupants should be empowered and motivated to use them correctly. The occupants should be aware of set targets for ener gy use, and how to optimally use the building. This will be included in the user's manual, and continuous feedback on the building's performance should be given.

Water harvesting

Rainwater will be harvested , stored, tested and used as greywater supply in toilets. When considering this system it is important to look past the financial savings and rather consider the ecological impact that this can have in the long term.

Total roof surface of the building on the site - including the Unisa Little Theatre, the Lutheran Church, the two proposed multi-functional buildings, the workshops and the performing arts centre = 7420m^2

Possible annual savings by using greywater for flushings of wc's and urinals instead of municipal piped water:

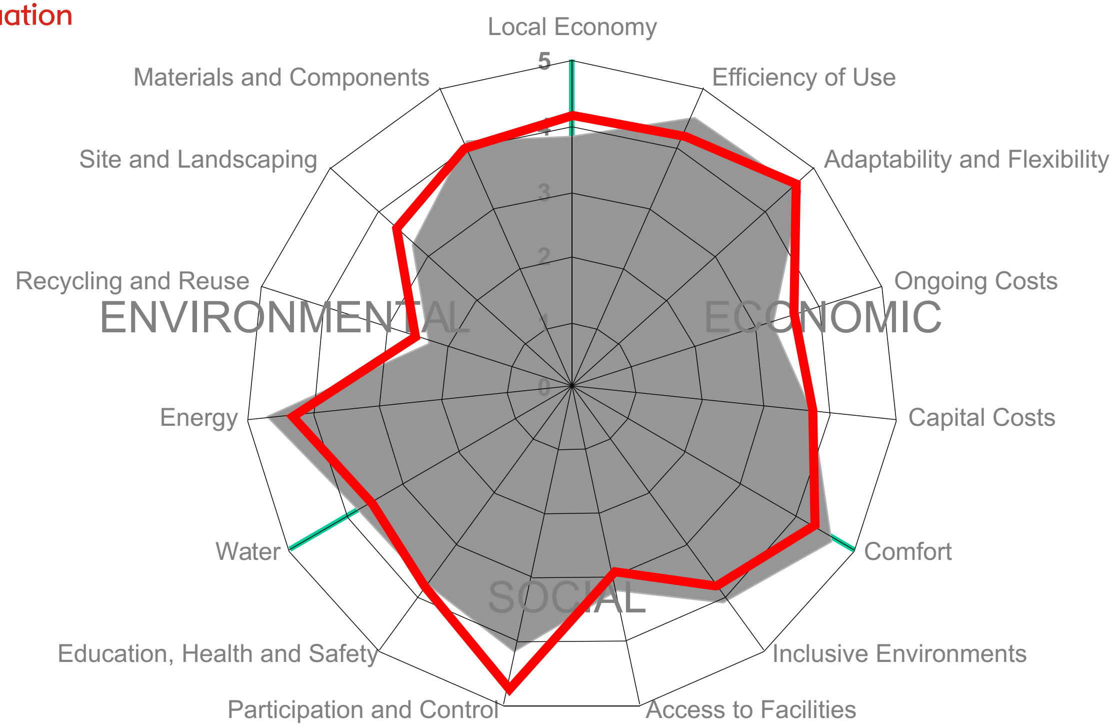
Harvested rainwater volume	=5515m^3
Current cost per 1m^3	=R3
	=5515 x 3
Possible annual savings	=R16500

Aggregate rainfall in mm/month for the Pretoria area:

Jan. -101.3mm
Feb. -108.8mm
Mar. - 63.8mm
Apr. - 37.5mm
May - 48.4mm
Jun. - 3.8mm
Jul. -2.3mm
Aug. - 2.3mm
Sept. - 11.3mm
Oct. - 82.5mm
Nov. - 168.8mm
Des. - 112.5mm

Potential annual rainwater harvesting volume:
Jan. - 751kℓ
Feb. - 807kℓ
Mar. - 473kℓ
Apr. - 278kℓ
May - 362kℓ
Jun. - 28kℓ
Jul. - 17kℓ
Aug. - 17kℓ
Sept. - 84kℓ
Oct. - 612kℓ
Nov. - 1252kℓ
Des. - 834kℓ
5515kℓ water per annum

SBAT Evaluation



Target Assessment

See appedix 1 for tables