Technical investigation

This chapter explores the technical investigation conducted for the dissertation. Various technical aspects have been illustrated, so that the reader can better visualise these technical aspects in relation to the spatial design of the project. Calculations into member and component sizes have also been included. Precedents which have aided in the technical decision making process have also been included in this chapter, These precedents have been chosen and investigated due to their similarities to this project and have been reinterpreted for the purpose of this dissertation.

Tectonic development

In order for the technical aspects of the project to appropriately strengthen the design, the tectonic development was informed by and based upon the theoretical argument. As the experience of space forms the basis of the theoretical argument and design decisions, this also informed and the guided the technical and tectonic choices. All experiences are to occur on a human scale, so that users can be made aware of the massing, spatiality, materiality and light quality within the building, and subsequently all decisions about material choices and construction systems not only had to satisfy the theoretical argument but had to relate to more practical constraints such as cost, thermal and acoustic properties and methods and ease of construction.

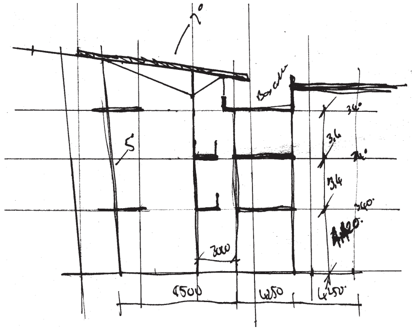


FIG 7.1_Development to central activity spine

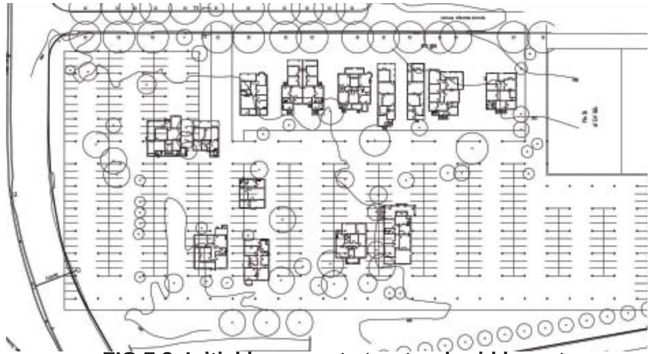


FIG 7.2_Initial basement structural grid layout

The process of the formulation of an appropriate and legible structural grid is shown in these sketches. Due to the large parking requirements of a building of this nature, the project includes a large super-basement on two levels, the structural grid of which was calculated according to the requirements for vehicular parking. This structural spacing will project vertically, forming the principal guiding structural layout for the building above.

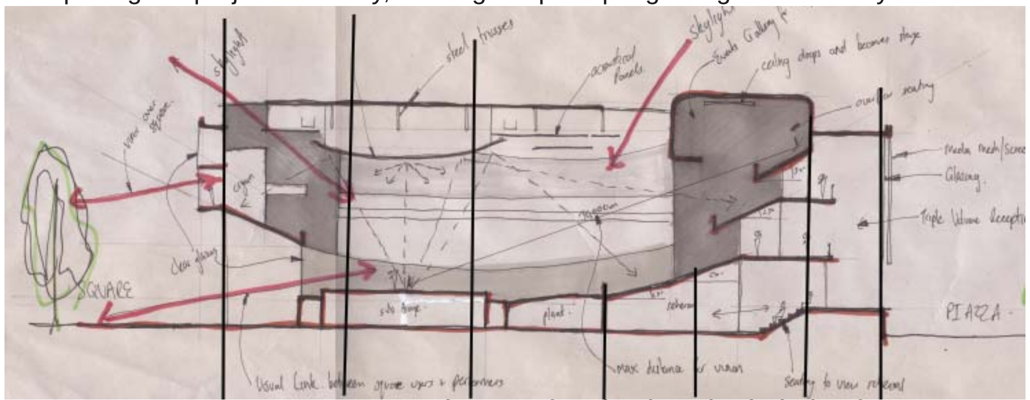


FIG 7.3_Development of section through principal performance space

The structure

The main body of the building's structure is comprised primarily of a reinforced concrete structure consisting of reinforced concrete floor slabs atop reinforced concrete columns and positioned according to a regular grid which was generated in response to the basement parking requirements.

External facades will either be treated with off-shutter concrete, glazed curtain walls, copper cladding, media screens, masonry face bricks or masonry clay stock bricks with a plastered finish. Internal walls will largely be constructed from masonry clay stock bricks with a plastered finish.

Two types of roofing systems have been used in the design of this cultural centre for the visual and performing arts, including low sloping reinforced concrete roofs and steel roofing systems. Low sloping reinforced concrete roofs will be used throughout the structure, except where spans have been determined to be to large for conventional concrete spans, and steel roofing systems have been employed. The central activity spine also has a steel roofing system to give the structure a lighter appearance.

Reinforced concrete structure and flooring

The main structure will be comprised of cast-in-situ reinforced concrete columns and slabs.

As the functions, spans, beam sizes and cantilevers of the building will vary, different columns will be subjected to different structural loading. However, it has been decided that the columns be in one of two dimensions, namely 690x330mm and round 690Ømm, the decision of which column to use where, will be based on aesthetical considerations and, where columns are subjected to greater loads, additional steel reinforcing will be added. The columns have all been designed to house a 100mm uPVC rainwater pipe, that will transport roof water to the storage water tanks in the basement. The 690x330mm columns have also been designed with chamfered corners to protect the edges and to accommodate 230mm walls which adds to the visual complexity of the building. All columns are located in accordance with regular structural grid of 8500mm x8500mm which is governed by the basement design and requirements.

In irregular shaped spaces such as the principal performance space and multi-purpose exhibition gallery, cast-in-situ reinforced concrete walls be used to provide vertical support.

For the floors, a two-way 340mm deep cast-in-situ reinforced concrete, flat slab construction has been chosen. It is generally accepted, that in the construction of buildings with irregular shapes and loading, this form of flat slab construction is more economical (Forster, 1975:241), and allows maximum design freedom (Foster, 1975:211). This form of construction and design also eliminates the need for deep beams and, even though it is a heavy floor, it is highly fire resistant.

As mentioned, throughout most of the structure a two way 340mm deep cast-in-situ reinforced concrete slab with a span of 8,5m will be used. This slab will be supported by 340mm-deep reinforced concrete beams introduced visually as part of the flat slab construction. In some cases, where there are heavy concentrated loads such as in the sloping principal performance space seating floor slabs, a diagonal beam will be introduce in order to disperse the load throughout the column members of the grid.

As an internal flexibility of space utalisation is required, there will be very few load bearing walls in the building as mostl load paths are to be restricted to the column and cast-in-situ reinforce concrete wall structure.

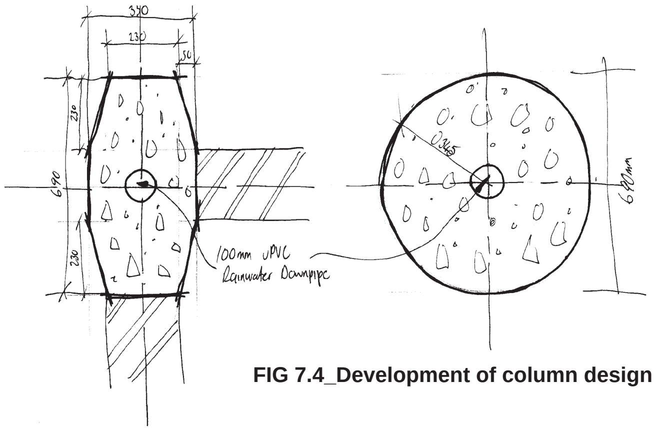


FIG 7.4_Development of column design

Calculations

Slabs: span/slenderness ratio
8500/30 = 283mm
therefore use 340mm slab

Columns: height/slenderness ratio
4760/15 = 317mm
therefore column min 330mm thick
NOTE: This was a guideline and was enlarged to house a 100mm RWDP

Multi-purpose exhibition space

The space has been conceived as a series of floating walkways on various levels that cantilever over a central space in order to create a sense of fluidity and movement. All activities and events housed within the structure are intended to be viewed from these cantilevered walkways giving the space a theatrical atmosphere.

The floor slabs of this space will be constructed of cantilevered 340mm deep cast-in-situ concrete slabs, supported by a continuous ring beam which will express the fluid qualities of the concrete. The 1 020mm deep ring beam will be supported on round 690mm concrete columns and the central service core with its 230mm cast-in-situ reinforced concrete wall.

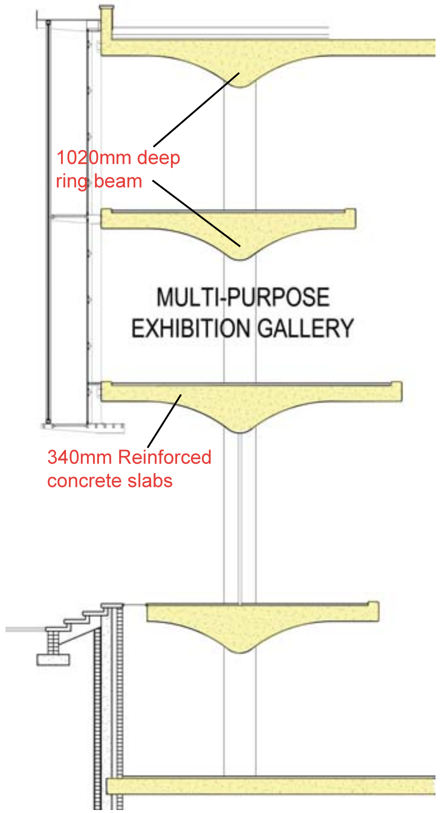


FIG 7.5_Section through structure of multi-purpose exhibition space

FIG 7.6_Structural layout of multi-purpose exhibition space

Principal performance space

The structure of the space is made up of cast-in-situ reinforced concrete slabs supported on cast-in-situ reinforced concrete walls and columns.

The layout and sizing of structural members is better understood graphically, thus please refer to images 7.7 to 7,9.

The floors slabs will mostly be constructed of 340mm deep 1 way cast-in-situ concrete slabs. Supporting columns are mostly 690mm in diametre and reinforced concrete walls are to be 345mm wid

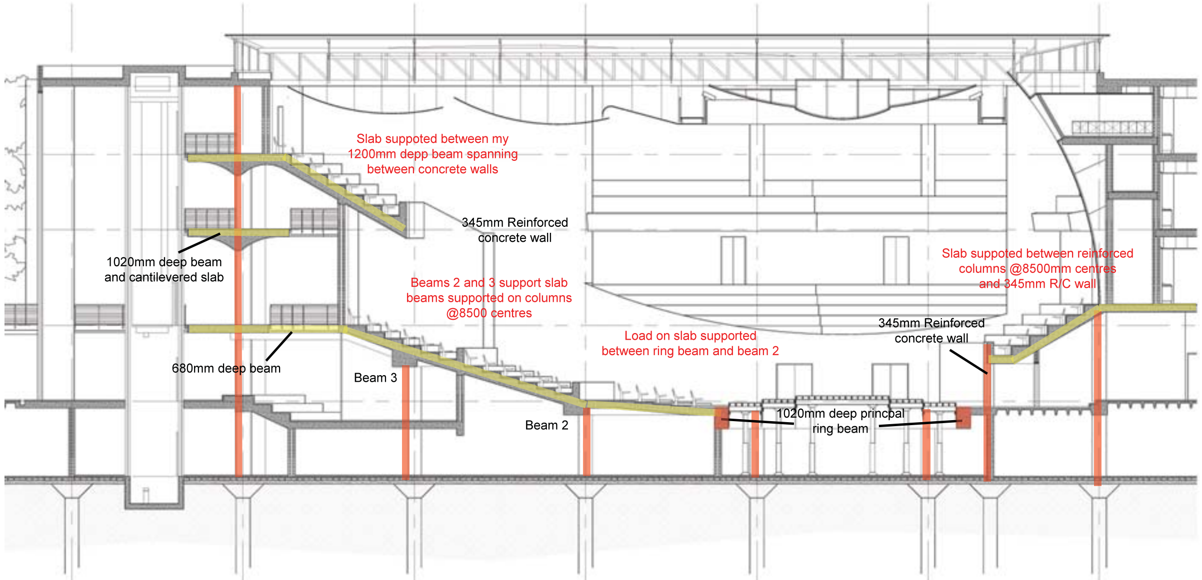


FIG 7.7_Section - structural layout of Principal performance space

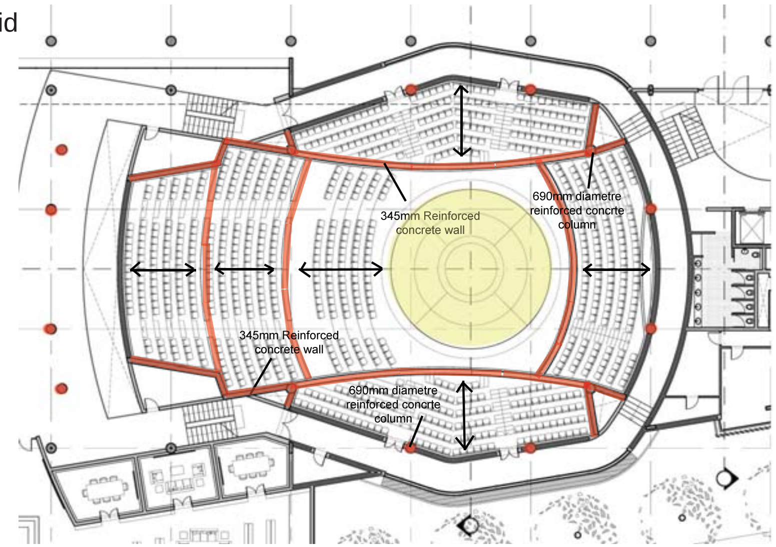


FIG 7.8_Plan - structural walls and columns

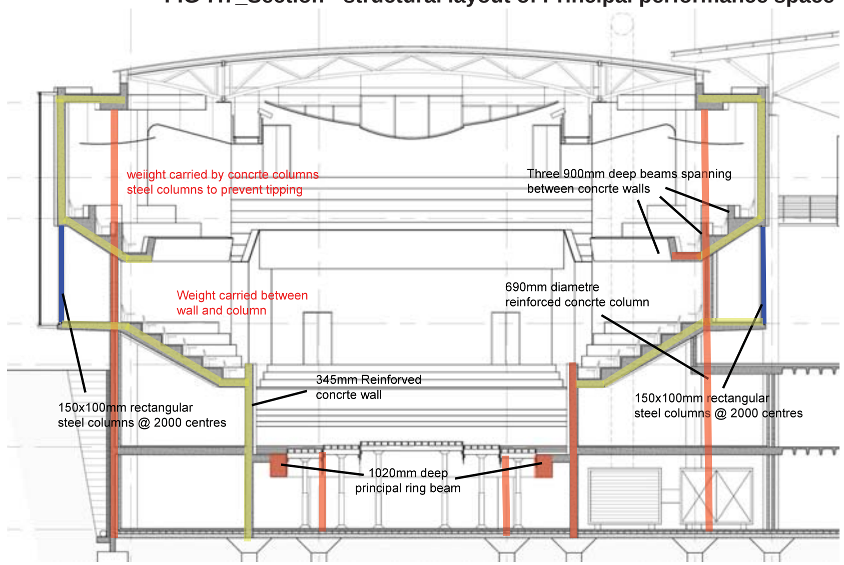


FIG 7.9_Section - Structural layout of principal performance space

Roofing Systems

Two types of roofing systems have been used in the design of this cultural centre for the visual and performing arts, including low sloping reinforced concrete roofs and steel roofing systems. These two systems have been chosen on the basis of system durability, material availability, maintenance intensity, aesthetical and technical implications, and cost.

Low sloping reinforced cast-in-situ concrete roofs will generally be used throughout the structure. and have been design with the falls strategically mapped to maximise the dispersion of rain water to the associated down pipes. The slope will be created by the installation of a low density sand-cement screed to a fall min 1:40. A layer of 100mm isoboard insulation will then be placed on top of the screed and waterproofed with a modified bitumen membrane, chosen because it is generally hard wearing and resistant to abuse. The roof will then be finished with prefabricated polymer-modified asphalt sheets placed on top of the modified bitumen membrane

The technical resolution of the steel roofing structures has required extensive research, investigation and thinking. Steel roofing systems have been used over the principal performance space, the secondary performance space and the central activity Spine. The technical resolution of each of is different from the others.

All roof sheeting is the be specified as superseal roof sheeting. This no-hole standing seam roof profile is specifically designed for slopes as low as 1 degree. The interlocking, concealed clip fastening system ensures a weatherproof roof. Unrestricted, extra long sheet lengths are possible by rollforming Superseal 500 on site.

FIG 7.10_3D - location of 3 main roofing systems

The principal performance space

The roof of the principal performance space will have to accommodate a large span of 19m in an east-west direction and 25,5m in a north-south direction. Thus, it has been resolved that two principal rolled steel trusses will span the 25,5m north-south span and secondary smaller curved rolled steel trusses at 4 250mm centres will be placed in the east-west direction. This roof design will also have to accommodate an adjustable space frame for lighting, as well as the mechanically operable, adjustable acoustic ceiling panel. This requirement for additional space will be accommodated for by the curved convex shape of the trusses, giving the additional ceiling height needed without increasing the height of the roof.

The inside of the roof will be finished off with a 15,5mm interior plaster board fixed onto a rigid support in the form of 10mm plywood boarding, which will in turn be fixed onto the secondary mild steel batons. 50mm acoustical glass fibre will be provided on top of the plywood boarding.

Refer to detail 3 on pg 167 for roof details

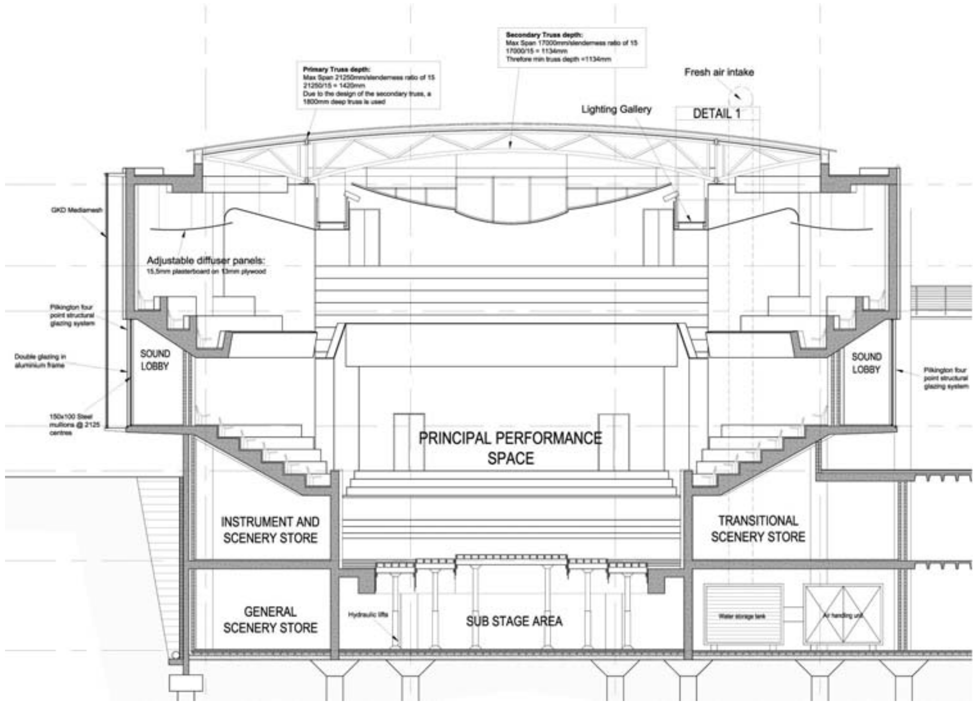


FIG 7.11_Roof profile over principal performance space

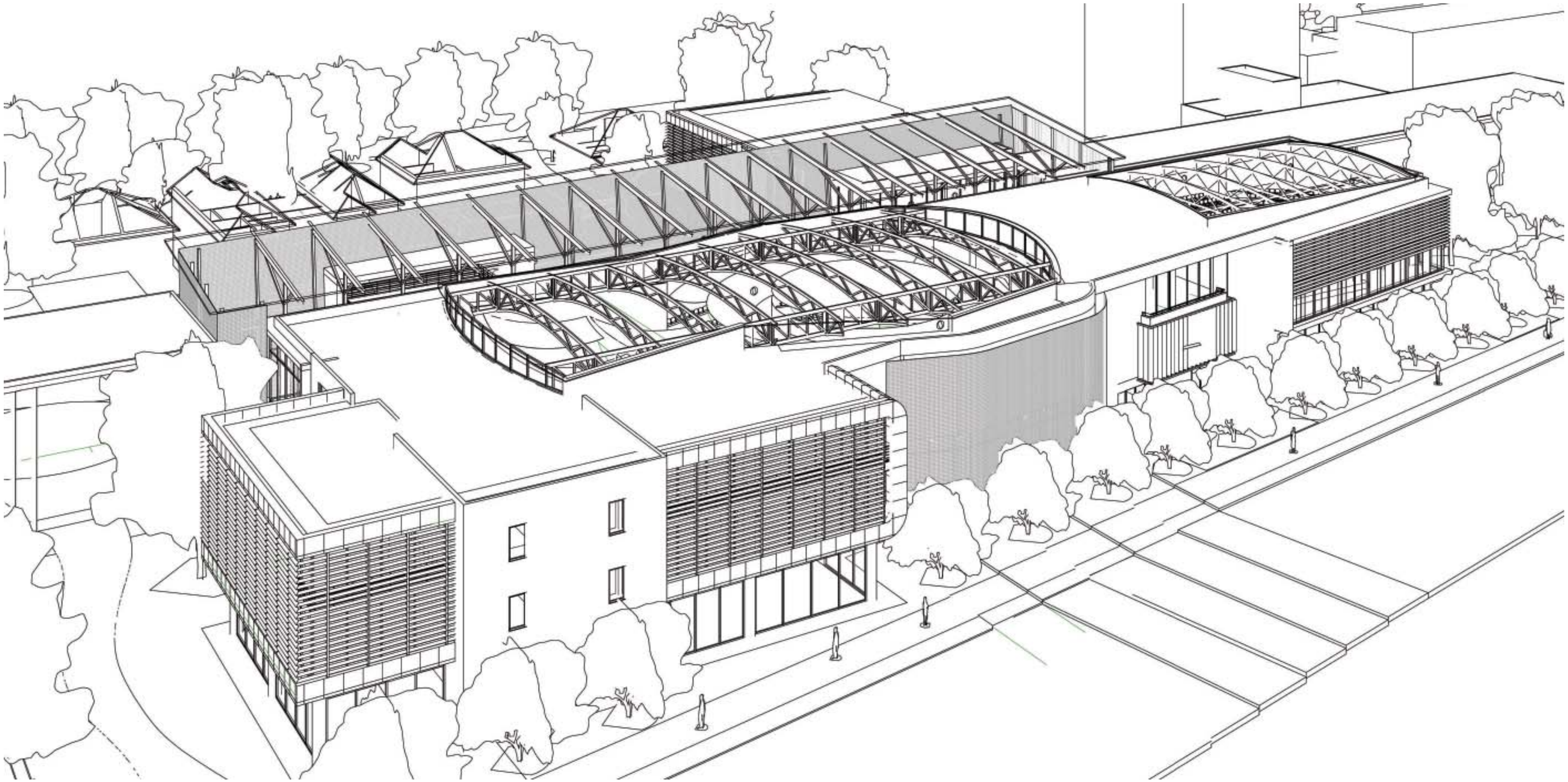


FIG 7.12_3D - Roof structure over principal and secondary performance spaces

Central activity spine

The roof of the central activity spine required roof a thorough investigation into the structural arrangement of the trusses, with the result that they are in most instances only centrally supported. The roof will be angled at 7 degrees and all trusses will be identical, except for the principal steel top chord of the truss which gets longer with each consecutive truss.

The roof will not be attached to any part of the building and through its sole central support, will appear to float above the space. The assembly of this roof is to be visible from the underside, so that the users of the space can understand how the space has been conceived and put together.

Refer to detail 7 on pg 171 for details

FIG 7.13_Precedent - Roof system along central circulation spine - New Law Building by Kruger Roos

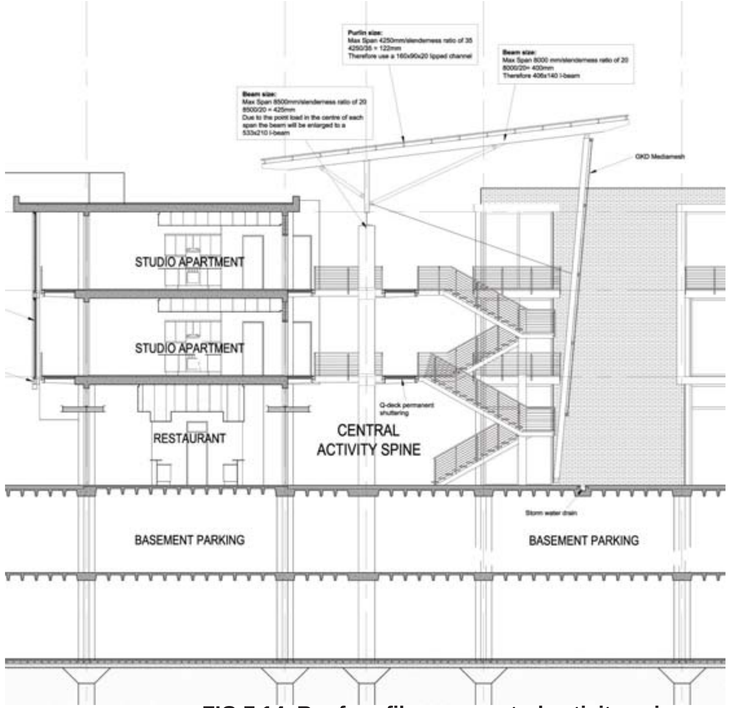


FIG 7.14_Roof profile over central activity spine

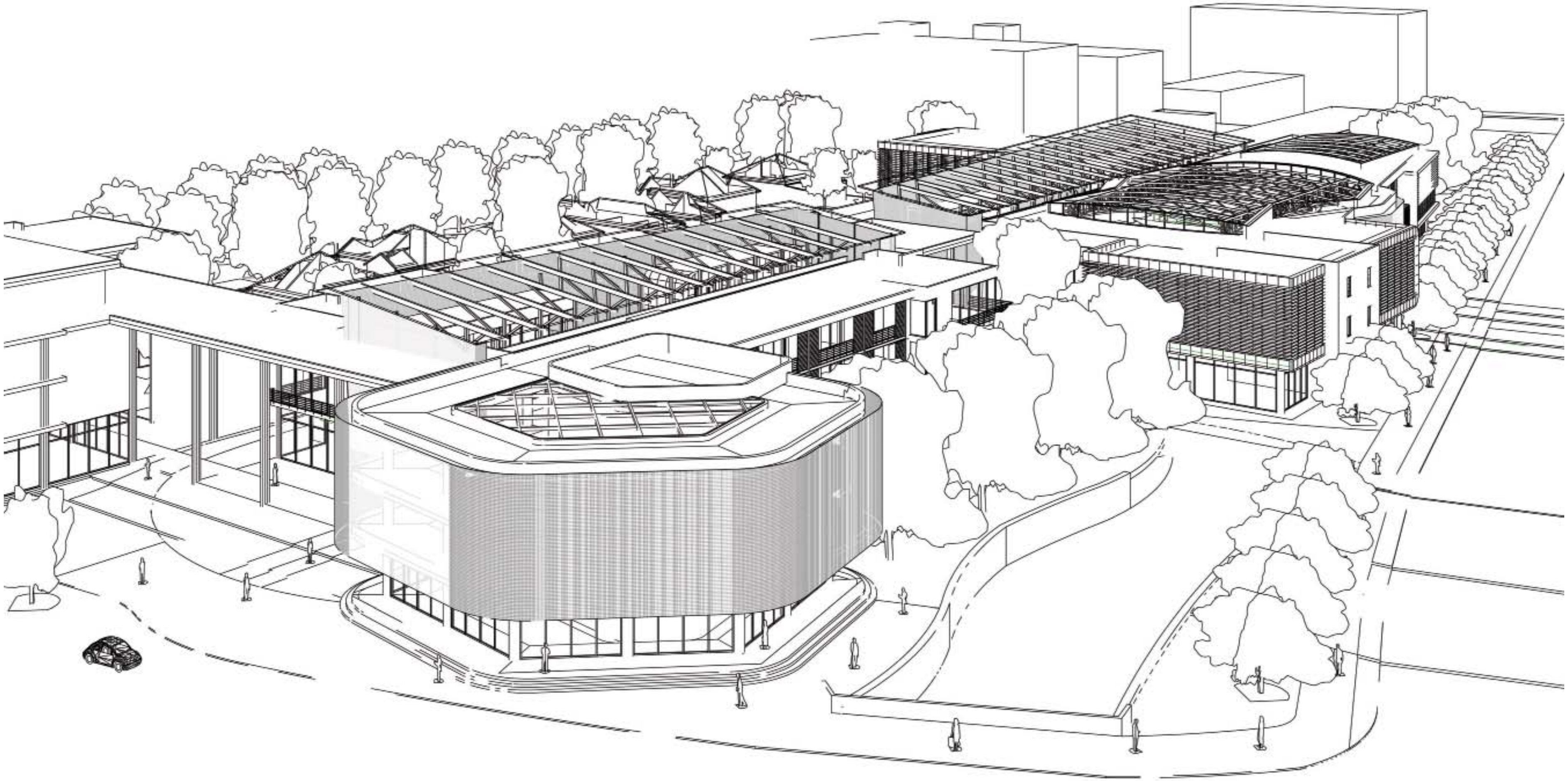


FIG 7.15_3D - Roof structure over central activity spine

Materials

Reinforced concrete

Reinforced concrete will be the principal structural material used in the cultural centre. Because a concrete structure is robust and requires little to no maintenance, all floors, columns and some roofs will be constructed from the material. Off-shutter methods for the cast-in-situ concrete walls will provide tactile textures to surfaces, and iron oxide pigment will add colour to the surfaces. The plasticity of concrete makes it possible to mould it into the complex forms required for the cast-in-situ walkways , the exhibition space and the terraced seating of the principal performance spaces.

FIG 7.16_Selected stock face brick

FIG 7.17_Off shutter concrete

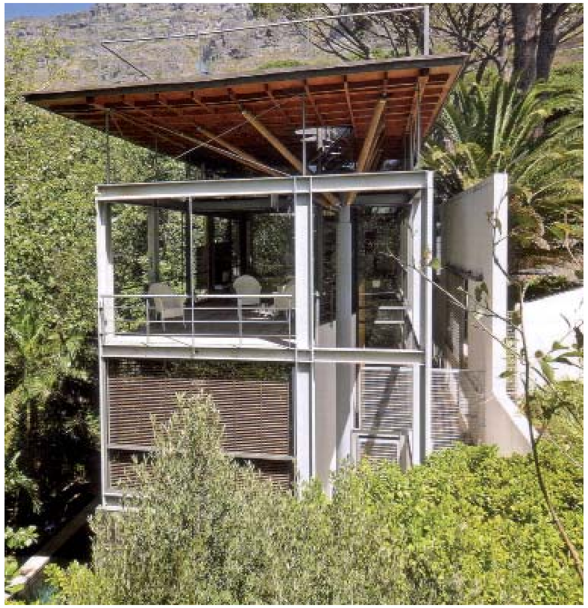


FIG 7.18_Structural steel

Brick

Brick is the principal vernacular building material in our country and is an integral part of the Pretoria aesthetic. Brickwork is a sustainable building material as it contains a low embodied energy and provides good thermal mass. It is also a very durable material and does not need very skilled labour to lay the material.

Steel

Steel will be used in the building to support the numerous skins of the building, including the digital media screens that wrap the centre and the shading devices. Steel will also be used as the structural support, frame and base for the central walkways and corridors that are housed in the central activity spine, as well as the balconies on the western edge of the artist apartments.

The slender nature of steel profiles will aid in the creation of a visually lighter skin. Steel structures can be easily adjusted or removed from the building and be recycled if necessary.

Copper cladding

Copper has been used as a construction material for centuries, and is a relatively low maintenance and durable material. However, proper design and installation are essential to ensure high quality, long-lasting installations.

Profiled copper panels, which are available in a variety of shapes and sizes and can also be pre-manufactured and specified with embossed patterns and designs, will be used to clad certain areas of the exterior of the centre. The copper panels are usually fixed to a 22mm shutterply substrate before they are fixed to the building in one of three ways: cleating, nailing, and screwing. All fasteners should be made of copper, a copper alloy or a neutral stainless steel alloy.

As copper and its principal architectural alloys are relatively active metals, when left unprotected they tend to oxidise and weather, which over a long period of time results in the formation of a naturally protective gray-green patina on the surface of the material. This natural weathering can, however, be hastened through chemical means and clear coatings. For this project, the material will be left to weather naturally over time, as copper tends to weather extremely slowly and maintain its lustre for decades.in the Pretoria climate.

Copper is mined locally in Phalaborwa, which makes it a sustainable building material, when-compared to other aluminium and stainless steel wall claddings.

FIG 7.19_Weathered copper cladding

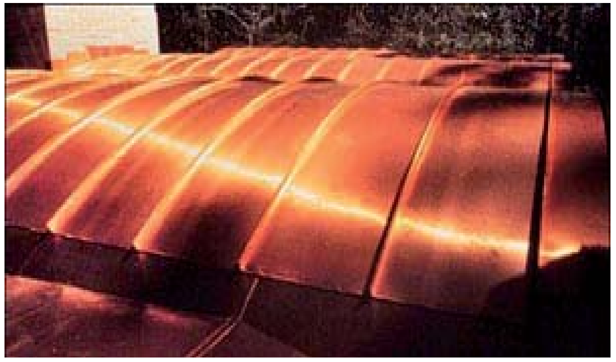


FIG 7.20_Chemically protected copper roof sheeting

FIG 7.21_Newly installed copper cladding

Glass curtain walls and exterior glazing

The project is intended to dissolve the boundaries between internal and external aspects of the centre. This can be achieved through the use of glass, which allows users of the square to see the performers and artists going about their everyday activities and enables them to learn more about the arts industry. The use of large expanses of glass also allows natural light into the building.

In recent years, glazing and window manufacturing has undergone a technological revolution. Numerous high performance, energy efficient window and glazing systems are now readily available. It is generally accepted that a reduction in the glazed surfaces in a building, will reduce energy consumption. However due to the required connection between the cultural centre and urban activity space, it is believed that large glazed facades and openings are necessary and the glazed facades will need to be protected from direct sun radiation.

In the cultural centre, most glazing will be fixed in aluminium frames as aluminium has a long life span and requires less maintenance than other window framing materials. In order to seamlessly link the activities of the centre to the square, sliding or sliding folding doors that can open up completely will be used. Giving the users of the spaces the option to open up or shut off their space, allows the user control over their immediate environment.

Pilkington Planar structural glazing systems have also been used on a numer of facades of the building. The system consists of structural glass which is fixed with spider glazing clamps to a secondary supporting structure. The advantage of this system is that the need for a fixed frame is eliminated and larger expanses of glass can be used. Curves can also be relatively easily created with the system. The structural glazing will also be coated with a UV resistant coating in order to dramatically reduce the ingress of long wave sun radiation into the building, preventing the ‘greenhouse’ effect that is usually associated with and created by large, glazed facades

Due to the large glazed surfaces on the facades of the building, numerous shading screens and devices will be used. Double glazing will also be used in instances where glazing on performance and rehearsal spaces occur, in order to reduce the heat gain and loss, and to reduce the ingress of noise into the performance spaces.

FIG 7.22_Precedent - Pilkington Structural glazing - Link building for the Institute of Infectious Diseases and Molecular Medicine

Floor finishes

Throughout the project, different floor surfaces are to be used to mark different movement routes and define specific interior and exterior spaces. Edges and thresholds are to be marked and defined by changes in material.

As most public spaces throughout the building will be subjected to heavy traffic, the floor finish needs to be robust. A 50mm cast-in-situ and power floated pigmented concrete screed will be cast on top of the reinforced concrete floor slab in all public areas. This screed will be sealed with polyurethane sealant in order to produce a hard-wearing floor finish. Mosaic and timber inlays as well as colour changes in the screeded floor are to be used to mark certain spaces and movement routes within the building.

The public square is be treated with a combination of different brick pavings. All pedestrian routes through the square and central spine are to be demarcated by an exposed aggregate concrete screed. Certain areas within the square are to be grassed and planted.

Upper floor walkways and movement spaces will be constructed from Q-deck permanent shuttering spanning between steel beams. The shuttering will be finished off will a 40mm pigmented screed. This type of construction will add to the light and transparent nature of the atrium space.

FIG 7.23_Precedent - demarcation of areas through differnt floor materials - De Beers Headquarters

FIG 7.24_Diffused light highlights differences in floor material

FIG 7.25_Pigmented screeded floors - Tolplan Head Offices

FIG 7.26_Mesh transparency when activated

FIG 7.27_Mesh creates multi-media experience on building facade

Digital screens

Many of the facades of the building are to be wrapped in digital mesh screens that will form the main façade elements on the eastern façade of the building facing the public activity square, as well as the principal performance space protrusion on the western facade and on the corner landmark that is the multipurpose exhibition space.

The idea behind the inclusion of media screens was to evoke an emotional connection between the observer and the architecture.
The screens will be linked to a computer system that, using a sophisticated audio scan, can turn pitch, rhythm and volume into changing digital patterns of colour and light. By doing this it is the intention that the building façade would be able to visually reproduce the music being played within the various performance spaces and create a powerful architectural expression of the performances inside the performance spaces. The screens will also display the works of artists, and can be used for advertising to defray running costs. One of the best characteristics of digital media is the opportunity for user interaction and participation. For expample, at certain times, through the use of cell phones and the internet, the public could control what is displayed on the screen. Any activity taking place on the square can also be projected on to the screens, increasing the visitors perception of the content of the media facade

Stainless steel mesh can be fixed and applied in various ways and the screens require little maintenance. They can also be recycled.

GKD Mediamesh and Illumesh systems will be applied to the proposed design

Mediamesh screens

Mediamesh screens are stainless steel mesh screens where interwoven LED profiles have been inserted at predetermined intervals into the mesh screen.

Control units are small and can easily be hidden in ceilings or in small dedicated control boxes. The images that are projected can be controlled from any internet connection point, making the system interactive and accessible to different users. The system can be used during the night or day times to display images, messages, art graphic, animations and even direct video displays.

The advantage of these screens is that they do not completely close off the façade of the building as it can appear either opaque or totally transparent, given the correct lighting conditions.

Illumesh screens

Illumesh is a more cost-effective option than Mediamesh screens. The screens reflect images outward from the inwards-facing LEDs. The LEDs are placed at less regular intervals thus making this system only suitable for large surfaces, viewed from greater distances.

FIG 7.28_GKD Mediamesh - LEDs inserted into stainless steel mesh

Circulation

One of the principal factors influencing the design outcome has been the treatment of the circulation through the building and square. The majority of the vertical and horizontal circulation is housed within or accessed from the central activity spine. The image below indicates the vertical and horizontal circulation through the building and between the spaces.

Principal spaces such as the multi-purpose exhibition space and principal performance space will have their own dedicated circulation cores due to the high traffic nature of these spaces at selected times. Shared public cores are scattered at strategically placed locations around the building, limiting travel distances. Performers will have their own dedicated circulation core separated from the public.

As this is a public building, it has been designed to be easily accessible to all members of the public. For example all public amenities will be accessible to people with disabilities. Disabled facilities will be provided on all floors and numerous lifts within the building will ensure easy access to all areas of the centre for people with disabilities.

Where ramps are deemed necessary they have been designed with maximum gradient of 1:12 as required by the building regulations.

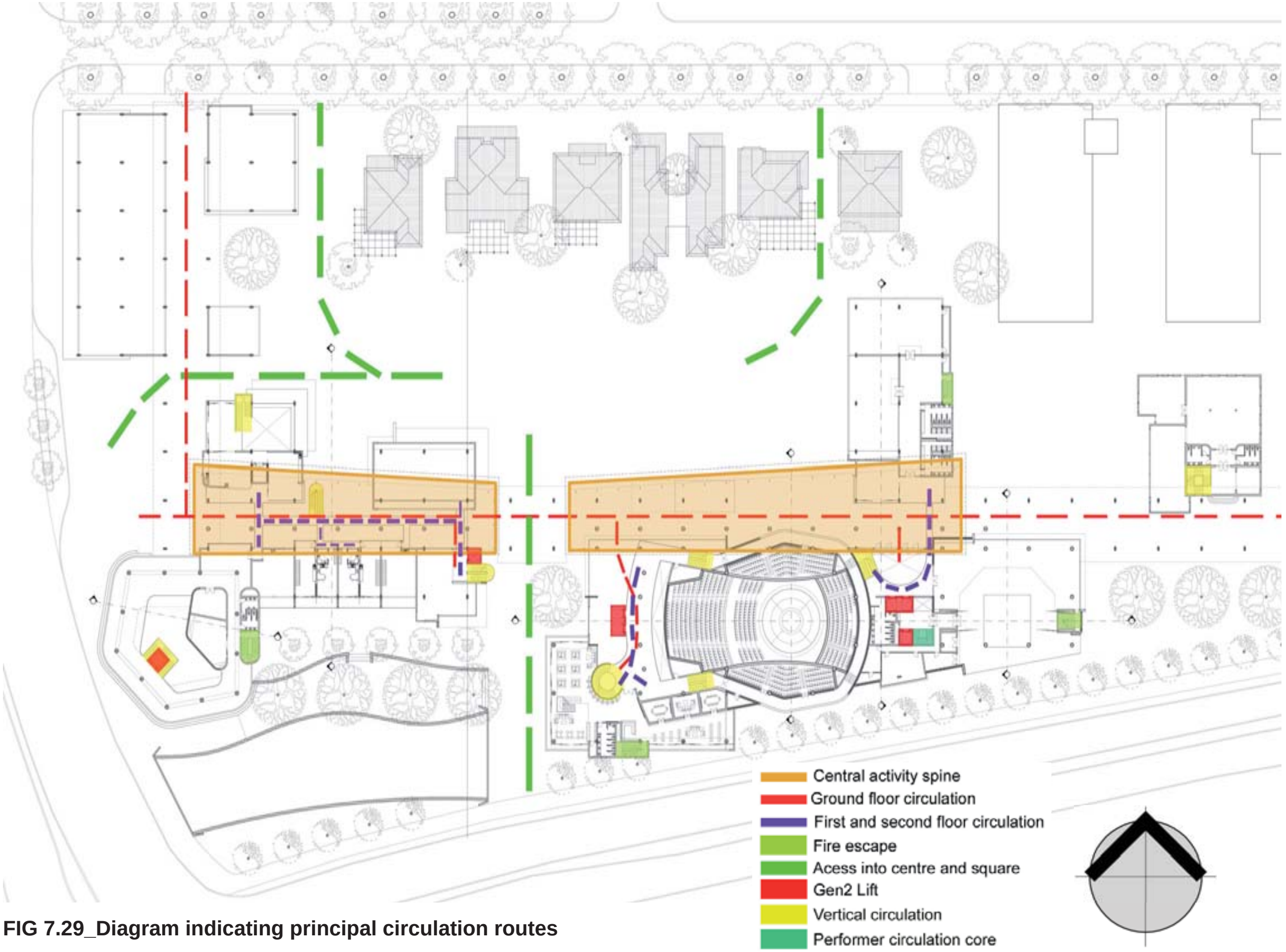


FIG 7.29_Diagram indicating principal circulation routes

Security

The centre has been designed so that all areas within the centre and the square can be observed through passive surveillance during the day and evening. All ground floor edges are active and informal activities are encouraged within the square and along the street edges, allowing, users to actively monitor the spaces. Artists' studios, galleries and dance studios as well as offices and retail spaces will be positioned above the square with a good viewing angle that will create a relative degree of control. Even though the building will be used throughout the day and night, additional security will be provided for at night to ensure the safety of users of the square when the space is less active.

Fire strategy

As the building is a public one, adequate safety for the centre's users in the event of fire must be provided for. A fire strategy specialist will have to be appointed who will ensure that an adequate fire protection plan is implemented.

The main first and second floor circulation of the north-western wing will be pulled away from and detached from the building addings to the safety of the occupants in case of fire.

The National Building Regulations(NBR) inform the proposed design in the following ways:

Travel distances to escape doors hwill have to be kept below 45m. As the building is more than 3 storeys high, each area within the building will be provided for with at least 2 escape routes.
All building materials in the emergency routes shall have a fire resistance of not less than 120 minutes.

The main structure of the building will be constructed from reinforced concrete, which has sufficient fire resistance. However, all structural steel elements are to be coated with an intumescent base coat to provide adequate protection from fire.

The basement will provided with three separate emergency route stairways, in accordance to the NBR.

Services and Climate Control

Services cores and ducts will be provided throughout the centre.

uPVC down pipes in all concrete columns will collect rain water from the various roofs of the centre. Water run-off from the square will be collected in a series of strategically placed catch pits located around the site. Both sources of water will be channelled to the 6 water catchment/storage tanks strategically located in different areas of the basement and will be used to cater for the landscaping requirements for this project. The water tanks will also be used to cool fresh air for the ventillation system, the details of which are later explained with the HVAC systems.

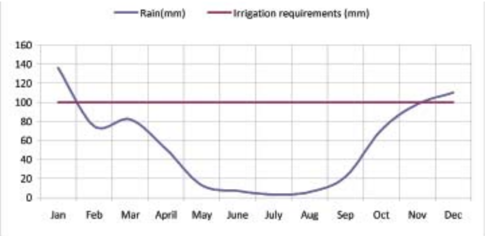


FIG 7.30_Graph - rainfall vs irrigation requirements

FIG 7.31_Graph - harvested water vs irrigation requirements

Water requirements for landscaping

Area of landscaping (m²) 6000m²
Water required for landscaping (Prof Vosloo) 100mm/month

Calculations:
Area of landscaping x 0,16 = Volume water required per month
6000 x 0,1 = 600 m³ per month

Therfore landcaping requies 600 kilolitres per month

Roof catchments

Catchment area (m²) 8340m²
Square area - paved areas (m²) 4220m²
Precipitation average annual in PTA (mm) 674mm
Run off coefficient 85%

Calculations:
Area of harvesting x Monthly rainfall x run off coefficient = Harvested water collected per month

Total annual harvested water 7323,74 kilolitres

	Rain(mm)	Shortfall/excess Rain (mm)	Harvested Water (kl)	Irrigation requirements (kl)	Difference (kl)
Jan	136	36	1451.94	0.00	1451.94
Feb	75	-25	800.70	150.00	650.70
Mar	82	-18	875.43	108.00	767.43
April	51	-49	544.48	294.00	250.48
May	13	-87	138.79	522.00	-383.21
June	7	-93	74.73	558.00	-483.27
July	3	-97	32.03	582.00	-549.97
Aug	6	-94	64.06	564.00	-499.94
Sep	22	-78	234.87	468.00	-233.13
Oct	71	-29	758.00	174.00	584.00
Nov	98	-2	1174.36	12.00	1162.36
Dec	110	10	1174.36	0.00	1174.36
	674		7323.74		

Water tank sizing

Water tank has been sized to store enough water for use through the winter months

Calcualtions:
Monthly rainfall - monthly landscaping requirements = Excess/shortfall of rain (mm)
Area of landscaping x monthly shortfall of rain/1000 in rain = Volume of water required for irrigation
Harvested water - irrigation requirements = Difference
Add all the months that have a negeative differnence to determine tank size.

Therefore according to the table above the tank must be:
May + June +July + Aug + Sept shorfall = **2149,52 kilolitres**

Therefore a tank of this size would enable all landscaping irrigation requirements to be harvested on site.

FIG 7.32_Calculations - irrigation requirements, harvested water, storage tanks

Ventilation

As the centre will house a range of facilities with different ventilation requirements, different areas and facilities within the centre will be cooled and heated in the manner, best suited to achieve the optimal indoor microclimate required for the functions of the respective facilities. This will also reduce the energy consumption of the building.

The residential apartment, studio apartment and studio layouts have been designed to allow for the natural cross ventilation of the spaces. However, if artists or residents do not want their doors to be open, fresh air will be provided by means of a mechanically regulated fresh air system. This system has been designed to draw fresh air in through intakes located alongside the Apies River channel, draw it through a piped radiator- like system located within the water tanks, cooling the fresh air down to just below natural air temperature, and distribute it to the required spaces.

The multi-purpose exhibition space is large enough to have its own dedicated cooling system. Since the space has a central atrium void, an evaporative cooling system is best suited to this environment. A evaporative cooler air handling unit located on the roof of the gallery will draw in outside air at roof height and distribute it to the various floors via a duct located in the central service core. The skylight over the central atrium void will have electronically controlled open able vents as part of its structure, which will be opened to release any built up heat accumulated at the top of the central atrium space. This induced stack effect will lower the atmospheric pressure on the interior, ensuring an optimum air change rate.

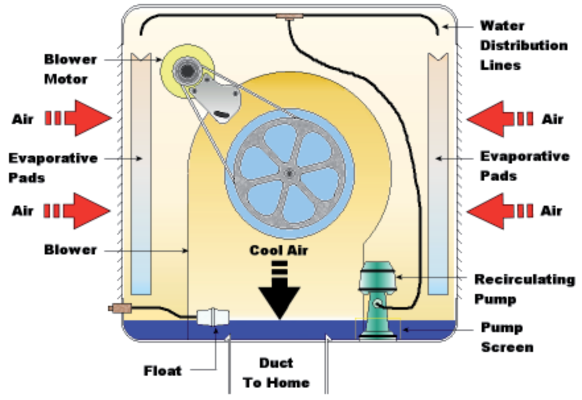


FIG 7.33_Evaporative cooling unit

Owing to the contained congregation of large numbers of people within the three main performance spaces as well as their supporting ancillary spaces such as dressing and rehearsal rooms, it has been decided that these spaces should to be serviced by dedicated air conditioning systems. Each performance space will have its own separate air handling unit sized and zoned to accommodate the varying requirements of the three spaces, such as the different requirements of the stage and audience seating.

Air handling units for the three spaces will be housed in a central plant room in the basement, to limit the acoustic impact it will have on performances and to allow for easy access when maintenance is required. Contact between all air handling units and the concrete floor slab must also be avoided in order to eliminate the possibility of resonating structural noise through the building. As a result, the air handling units are to be fitted onto a hollow section bracing structure that is to be fixed to the floor via a flexible suspension system.

The supply for the principal performance space is bought from the air handling units in the basement through a series of specially provided ducts. The air will then be bought into the space at various levels. The lower seating areas will receive ducted supply from floor vent, while the upper gallery spaces will receive air from ducts and vents located in the ceiling. All exhaust air wil be removed through the ceiling plenum and discharged through the roof above the ancillary spaces core. Transfer ducts will be specified at all acoustically rated partitions.

Humidity levels in the auditoriums must be kept constant at approximately 45% to 50%. A humidity control based on relative dew point is thus required, maintained by determining absolute humidity in the return air lines, outside conditions and treatment plant (National Institute of Building Sciences, 2005)

Owing to the open nature of the public foyers of the various performance spaces, these spaces will be cooled through natural ventilation by exploiting prevailing wind conditions specific to the site, with prevailing winds from north-east in summer and from the south-east in winter. The double volume nature of the space will assist in generating differences in air pressures in order to cool the space, as the warm air at the top of the volume be will mechanically extracted through the roof

Owing to the limited openings in the basement it will have to be mechanically ventilated.

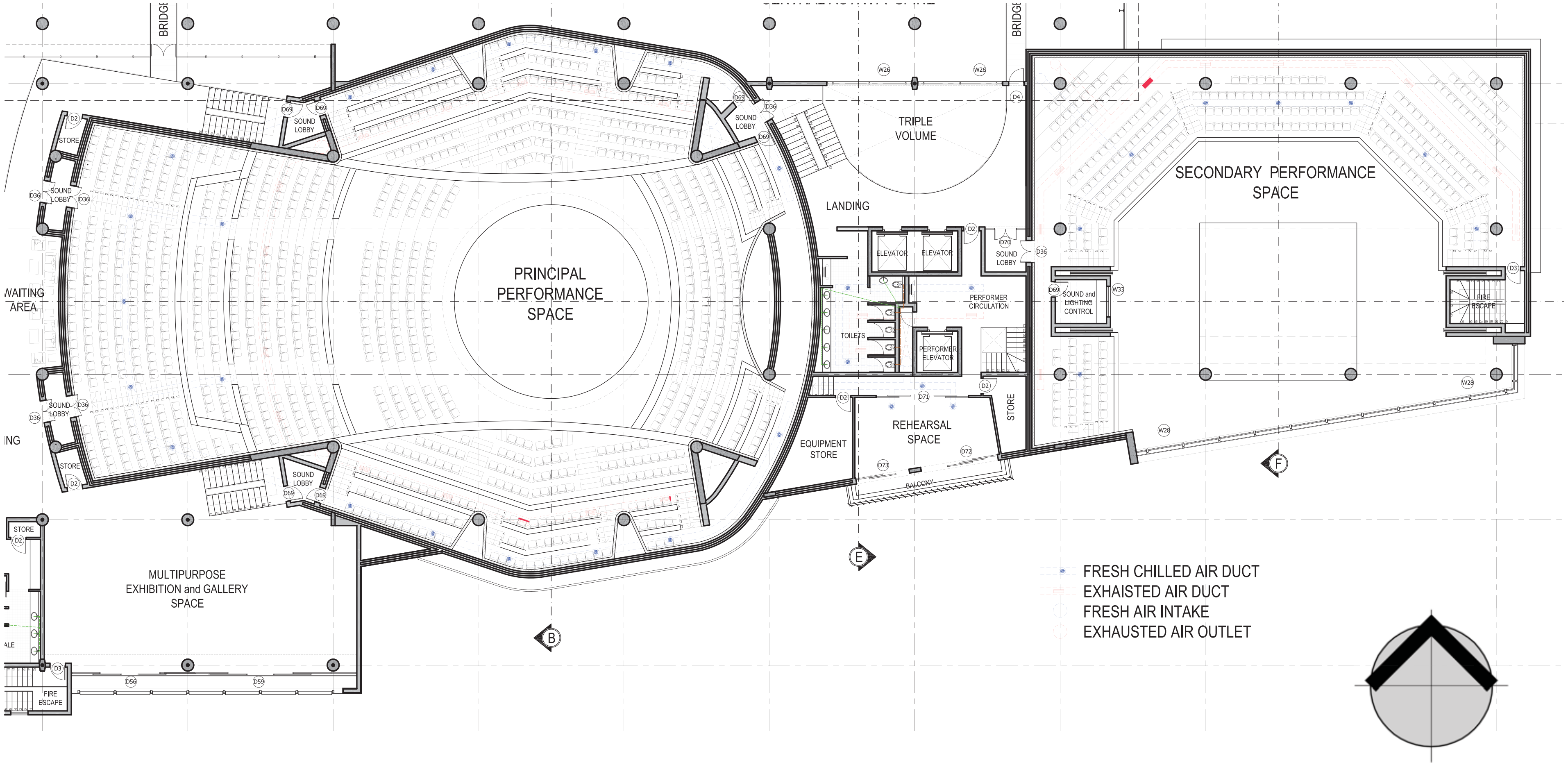


FIG 7.34_Principal and secondary performance space HVAC system

Solar gain and incidence

In all buildings with prominent glass facades, the issue of solar gain is a concern. The proposed design, intends to reveal the full extent of the inner workings of the visual and performing arts worlds to the passing public and users of the public activity space. This has led to a design that calls for extensive glass frontage on the eastern and northern facades surrounding the public open space.

Solar radiation is short wave in frequency. This direct short-wave radiation impacts the surface and, depending on the thermal mass and density of the material, is re-radiated after a time in the form of long wave radiation (Givoni, 1969:208). When short wave radiation hits a glass surface, some of the radiation is reflected and some of it is absorbed into the mass of the glass, while most of it travels through the glass in the forms of long wave radiation

Long wave radiation cannot escape through the glass, resulting in the' greenhouse effect'. It is thus imperative that, in the case of glass facades, the glass be shaded from direct radiation. Three structural techniques will be applied to adequately shade the glass during critical periods of the day: overhangs, the horizontal and vertical placement of louvers where no overhang exists and the placement of reflective and insulative panelling.

Large portions of the building will be wrapped in a second stainless steel mesh skin, which provides adequate sun protection for the glazed surface. In all other instances adequate shading devices have been installed in a somewhat reactionary fashion to shade the glazed surfaces.

Orientation

Due to the nature of the site and urban context, the architectural response is predominantly east-west facing. This orientation is not ideal in sustainable building practice terms but will be effectively dealt with by limiting the glazed openings on the western façade and by creating a secondary skin in the form of the activity spine on the eastern façade. Where openings occur on the western elevation, movable screens will be included.

The design has also been stepped so that a greater number of northern facades is achieved.

Thermal massing

Thermal mass is provided through the inclusion of the flat concrete roof and exterior walls of the building. Direct solar radiation is absorbed during day and the accumulated heat will be radiated into the interior spaces at night time.

Acoustics

Noise Control

The cultural centre for the visual and performing arts is located alongside busy Nelson Mandela Drive, and there will be a certain ingress of external vehicular noise into the centre. However, in a centre of this nature it is important that the quality of sound and performance be maintained. Transparent noise during peak traffic hours will produce a noise level of approximately 75 to 80 dB (Ariba, 1971:140), and as the centre is designed to incorporate a public urban activity square, pedestrian noise can also create a problem as it can reach levels of 65 to 70dB when the square is heavily occupied (Ariba, 1971:140).

Areas within the centre will require specific sound considerations (Lawson, 1981:71, 88, 170):

- Performance and rehearsal spaces require an ambient noise level maximum of 15dB to 30dB
- The multi-purpose exhibition spaces and visual material and music resource library has less stringent noise restrictions of 35dB to 38dB
- Finally the offices and dressing rooms must restrict the level of noise to 59 dB.

As the secondary performance space is to house performances of a more theatrical and dramatic nature, the internal environment must be kept silent where the clarity of the actors speech is essential.

Cavity walls have superior sound insulative properties compared to conventional masonry wall construction, because air is a weak conductor of sound. Thus, cavity walls will be employed around all performance spaces. The addition of acoustic insulation layers of 50m glass wool into the cavity will also increase the walls noise insulation properties, reducing the noise levels by 59dB (Egan,1988:204) .

High-mass materials are considered to be the best insulators of sound. As a rule of thumb, the thicker the wall, the less sound and noise penetration. For example a typical rendered 110mm masonry wall reduces noise by approximately 46dB, whereas a 220mm thick wall reduces noise levels by approximately 55dB (Lawrence, 1989:120).

Ingress and the loss of sound/noise through doors have also been addressed. Sound lobbies with a double door configuration will effectively act as a large cavity between foyer and performance space, limiting the ingress and loss of sound/noise, and will thus be introduced into all performance spaces. For maximum results, all performance space doors will be specified as solid core 50mm hardwood veneer double doors with gasket and drop seal which will reduce noise ingress by 43dB (Egan,1988:204)

Rehearsal spaces with glazed walls will be introduced adjacent to the lower ground floor foyer, to activate the foyer and provide the audience with a pre-show that excites them about the main performance. Glazed facades will also be included in the secondary performance space and studio theatre. Subsequently the sound insulating properties of the glass must be optimal. Double glazing positioned within aluminium frames will be specified due to aluminium's ability to achieve tight seals, which is integral for sufficient sound isolation. In addition to the use of double glazed windows, an additional outer Pilkington structural glazing wall with air gap between the two skins to further reduce noise ingress. Double glazing has a sound reduction capacity of up to 43dB and the Pilkington structural glazing system of 33dB (www.pilkington.com). The combination of these two glazed elements is believed to be a sufficient defense against the ingress of exterior noise.

Acoustic isolation calculations

Construction	Ia Index (dB)
Walls	
115mm brick + 115mm cavity with glass fibre insulation + 115mm brick (Egan, 1988:204)	59
345mm solid concrete (Egan, 1988:204)	56
220mm masonary wall (Lawrence 1989:120)	55
110mm masonary wall (Lawrence 1989:120)	46
Floor Ceiling	
340mm reinforced concrete (Egan, 1988:204)	55
Glazing	
Double Glazing (Aluglass,2007)	43
Pilkington structural glasing (www.pilkington.com)	33
Doors	
50mm solid core hardwood veneer double doors with gasket and drop	43

Principal performance space (15 -30dB)

Internal sound level = External noise level - STC
= 70dB - 59dB (Cavity wall with glass insulation)
= 11dB therefore audible

Multipurpose exhibition space (35 -38dB)

Internal sound level = External noise level - STC
= 70dB - 33dB (Pilkington structural glazing)
= 37dB therfore audible

Dance studios and rehersal spaces (15 - 30dB)

Internal sound level = External noise level - STC
= 70dB - 43dB (Double glazing)
= 27dB therfore audible

Offices and dressing rooms (max 59dB)

Internal sound level = External noise level - STC
= 70dB - 55dB (220mm masonary wall)
= 15dB therfore audible

FIG 7.35_Acoustic isolation calculations

Performance space acoustics

Principal performance space

The form and initial plan dimensions of the principal performance space were established through a rough initial estimate of the required audience capacity. This was determined to be 1 350 people based upon figures provided by the State Theatre. The principal performance space is to house concerts and other musical performances by choirs, orchestras and bands, operatic performances, and dance performances such as ballet and modern dance as well as cultural and theatrical performances.

Musical theatres/auditoriums for performances require a volume of roughly 6 to 9 cubic metres per person, while spaces for theatrical performance require a volume of 3 to 4 cubic metres (Rettinger, 1968:245). The volume of the principal performance space was determined from these figures. In order to accommodate both types of performances, the ceiling height of the inverted suspended ceiling of the auditorium could be adjusted to adjust the volume of the space, when required.

The volume of the space is also a contributing factor in determining the reverberation times of the performance space. Reverberation is the persistence of sound in a particular space after the original sound is removed. A reverberation is created when a sound is produced in an enclosed space causing a large number of echoes to build up and then slowly decay as the sound is absorbed by the walls and air. The length of this sound decay, or reverberation time, must receive special consideration in the planning of large performance spaces in order to achieve optimum performance (Rettinger, 1968:200).

Different performance spaces also have different acoustic setting requirements. Musical performances require imposed echoes of limited proportions with a reverberation time of approximately 1,2 to 1,4 seconds for optimal performance, while theatrical performances, where audible speech is more intelligible through an instantaneous audible reception with no echoes, a reverberation time of approximately 0,8 to 1,1 seconds is optimal (www.reverberationtime.com)

As the changes in the volume of the space through the adjustment of the ceiling will not solely influence the reverberation time of a building, and as the interior acoustics need to accommodate for speech and musical performances, appropriate acoustical performance is to be achieved through electronic augmentation. This augmentation is widely believed to far surpass the acoustical performance capabilities offered by the ‘traditional’ theatre and concert halls which use the principal of bouncing sound off walls and ceilings (Lawson, 1981:185). So, the reverberation time required for each performance may be systematically predetermined for each performance. Electronically operated speakers will be housed in strategically placed positions throughout the performance space, to discharge sound at a favourable rate and volume.

Even though electronic augmentation of the acoustic qualities of the principal performance space will be employed, adequate and careful planning and calculating must still be done of the absorptive and reflective capacities within the performance space.

The space has thus been designed to contain a minimal reverberation time so that the space is ideal to receive all manner of electrical augmentation and induced reverberation of up to 1,3 seconds depending on the requirements of the performance.

The principal performance space in order to achieve a greater intimacy between the audience and performers has been designed to wrap the stage resulting in many curved walls and curvilinear surfaces. These walls create haphazard sound reflections and therefore are to be acoustically dampened with the locally produced Mellosorber acoustic absorbent panels which inhibits the return of echoes. The height of the adjustable ceiling has been designed in the form of a curved reflective suspended ceiling (vinyl finish on 13mm plywood) in the shape of an inverted dome, and will be hung over the stage to reflect all sound radiating from the stage towards the audience. This, together with a reflective rear curved panel will be the only reflective surfaces located near the stage to limit uneven sound distribution. The reflected travel distance of sound through the air has been limited to 12m, to prevent undesirable attenuation inaudibility (Ham 1972:37)

Diffuser panels (15,5mm plasterboard on 13mm plywood) will be placed in the ceiling and designed to direct the sound of the electronic augmentation, so as to not direct the sound radiating from the stage. These panels could be retracted into the ceiling void if needed and will be angled at a minimum slope of 4 degrees to prevent stationery sound waves from forming and creating flutter echoes (Rettinger, 1968:87). The diffuser panels, which will be slightly curved and randomly placed throughout the space are recommended to range from 0,8m² to 3m² in area (Rettinger, 1968:87).

Principal performance space - Unoccupied

	Absorbtion at frequency						
	125	250	500	1k	2k	4k	
Side walls (front 1/3 of space)							
15.5mm plasterboard and 13mm plywood on studs (10mm air gap)	0.29	0.1	0.05	0.04	0.07	0.09	
220m²	63.8	22	11	8.8	15.4	19.8	
Side walls (back 2/3 of space)							
Mellosorber acoustic absorbent panel on spacers (60mm air Gap)	0.41	1	1.11	1.14	1.05	1.05	
470m²	192.7	470	521.7	535.8	493.5	493.5	
Rear walls							
Mellosorber acoustic absorbent panel on spacers (60mm air Gap)	0.41	1	1.11	1.14	1.05	1.05	
190m²	77.9	190	210.9	216.6	199.5	199.5	
Rear Wall behind stage							
Mellosorber acoustic absorbent panel on spacers (60mm air Gap)	0.41	1	1.11	1.14	1.05	1.05	
70m²	28.7	70	77.7	79.8	73.5	73.5	
Refelective rear curved wall panel							
Vinyl on 13mm plywood	0.02	0.03	0.03	0.03	0.03	0.02	
90m²	1.8	2.7	2.7	2.7	2.7	1.8	
Floor							
Heavy carpet on foam	0.08	0.24	0.57	0.69	0.71	0.73	
1020m²	81.6	244.8	581.4	703.8	724.2	744.6	
StageFloor							
Wooden floor	0.15	0.11	0.1	0.07	0.06	0.07	
100m²	15	11	10	7	6	7	
Ceiling							
15.5mm plasterboard and 13mm plywood on studs (10mm air gap)	0.29	0.1	0.05	0.04	0.07	0.09	
620m²	179.8	62	31	24.8	43.4	55.8	
Ceiling							
Off shutter concrete	0.01	0.02	0.04	0.06	0.08	0.1	
240m²	2.4	4.8	9.6	14.4	19.2	24	
Refelective adjustable ceiling							
Vinyl on 13mm plywood	0.02	0.03	0.03	0.03	0.03	0.02	
165m²	3.3	4.95	4.95	4.95	4.95	3.3	
Seating							
Upholstered fabric seats	0.49	0.66	0.8	0.88	0.82	0.7	
S = 1350m²	661.5	891	1080	1188	1107	945	
Average absorbtion coefficient (a)	1308.5	1973.25	2540.95	2786.65	2689.35	2567.8	
Total suface area (S) = 4415m²							
Volume (V) = 10800m³							
0,161V = 1738.8m³							
Sabine RT	1.33	0.88	0.68	0.62	0.65	0.68	reverberation time

Principal performance space - Occupied

	125	250	500	1k	2k	4k	
With audience of 1350							
Upholstered fabric seats	0.6	0.74	0.88	0.96	0.93	0.85	
S = 1350m²	810	999	1188	1296	1255.5	1147.5	
Average absorbtion coefficient (a)	1457	2081.25	2648.95	2894.65	2837.85	2770.3	
0,161V = 1738.8m³							
Sabine RT	1.19	0.84	0.66	0.60	0.61	0.63	reverberation time

FIG 7.36_Principal performance space - reverberation calculations

Secondary performance space

The secondary performance space has been designed to be used in a variety of configurations for a variety of performances. The acoustics in this space are electronically augmented and the dimensions of this performance space also ensure that no seat is distanced at more than 20m from the source of stage, which is a requirement for the audible reception of speech in performances of a dramatic nature (Ham, 1972:36). Reflective panelling suspended from a space frame in the ceiling and the external walls will also be clad in Mellosorber acoustic absorbent panels.

Sustainability

The rating system chosen to test the sustainability of the building is the Sustainable Building Assessment Tool (SBAT) rating system developed by the CSIR. It was chosen as it has been developed to relate to the South African context and is designed to support sustainable development.

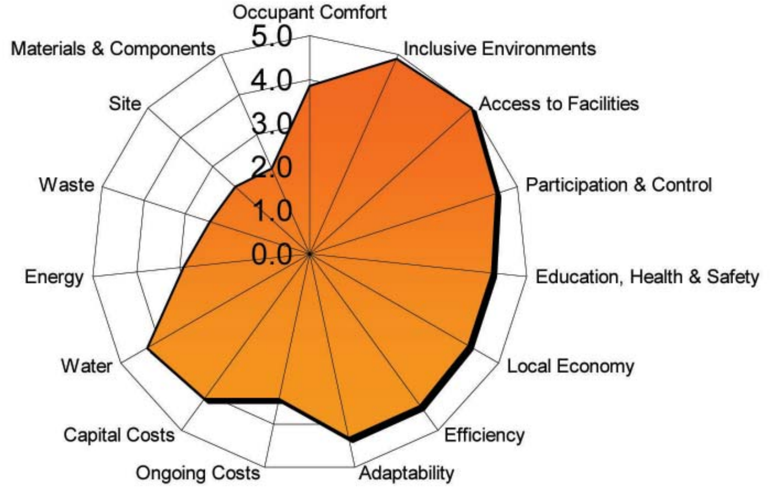
The system describes 15 sets of objectives, under the subjects of economic, environmental and social, that should be aimed for in buildings. The system works by accessing to what extent these 15 objectives are achieved in the building

Economic: Local economy, efficiency of use, adaptability and flexibility, ongoing costs, capital costs
Environmental: Water, energy, waste, site, materials and components
Social: Occupant comfort, inclusive environments, access to facilities, participation and control, education, health and safety

The building has achieved a rating of 3.8 which is considered to be good. Social and economic objectives have been suficiently met, however the environmental objectives have not been so easily achieved. This is because objectives such as the use of renewable energy resources and on-site sewerage treatment were decided against due to the initail capital outlay as well as the space con-

SUSTAINABLE BUILDING ASSESSMENT TOOL (SBAT- P) V1

PROJECT	
Project title:	Genius Loci - A cultual centre for the visual and performing arts
Location:	Mandela Development Corridor
Building type:	Cultural centre for the visual and performing artrs
Internal area (m2):	17223m²
Number of users:	2000 (average estimate at peak)



Social	4.5	Economic	4.1	Environmental	2.8
Overall	3.8	Classification:	Good		

FIG 7.35_(SBAT) assessment results

Building Performance - Social

	Criteria	Indicative performance measure	Measured	Points
SO 1	**Occupant Comfort**			3.9
SO 1.1	Daylighting	% of occupied spaces that are within distance 2H from window, where H is the height of the window or where there is good daylight from skylights	70	0.7
SO 1.2	Ventilation	% of occupied spaces have equivalent of opening window area equivalent to 10% of floor area or adequate mechanical system, with upolluted air source	80	0.8
SO 1.3	Noise	% of occupied spaces where external/internal/reverberation noise does not impinge on normal conversation (50dbA)	75	0.8
SO 1.5	Thermal comfort	Temperture of occupied space does not exceed 28 or go below 19oC for less than 5 days per year (100%)	80	0.8
SO 1.5	Views	% of occupied space that is 6m from an external window (not a skylight) with a view	80	0.8
SO 2	**Inclusive Environments**			4.9
SO 2.1	Public Transport	% of building (s) within 400m of disabled accessible public transport	100	1.0
SO 2.2	Information	High contrast, clear print signage in appropriate locations (100%)	100	1.0
SO 2.3	Space	% of occupied spaces that are accessible to ambulant disabled / wheelchair users	90	0.9
SO 2.4	Toilets	% of space with fully accessible toilets within 50m	100	1.0
SO 2.5	Fittings & Furniture	% of commonly used furniture and fittings (reception desk, kitchenette, auditorium) fully accessible	100	1.0
SO 3	**Access to Facilities**			5.0
SO 3.1	Children	All users can walk (100%) / use public transport (50%) to get to their childrens' schools and creches	100	1.0
SO 3.2	Banking	All users can walk (100%) / use public transport (50%) to get to banking facilities	100	1.0
SO 3.3	Retail	All users can walk (100%) / use public transport (50%) to get to food retail	100	1.0
SO 3.4	Communication	All users can walk (100%) / use public transport (50%) to get to communication facilities (post, telephone and internet)	100	1.0
SO 3.5	Exercise	All users can walk (100%) / use public transport (50%) to get to recreation / excersise facilities	100	1.0
SO 4	**Participation & Control**			4.5
SO 4.1	Environmental control	% of occupied spaces able to control their thermal environment (adjacent to openable windows/thermal controls)	70	0.7
SO 4.2	Involvement	% of users actively involved in the design process (workshops / meetings with models / large format drawings)	80	0.8
SO 4.3	Social spaces	Social informal meeting spaces (parks / staff canteens / cafes) provided locally (within 400m) (100%)	100	1.0
SO 4.4	Sharing facilties	5% of facilities shared with other users / organisations on a weekly basis (100%)	100	1.0
SO 4.5	User group	Active representative user group involved in the management of the building / facilities / local environment (100%)	100	1.0
SO 5	**Education, Health & Safety**			4.2
SO 5.1	Education	Two percent or more space/facilities available for education (seminar rooms / reading / libraries) per occupied spaces (75%). Construction training provided on site (25%)	100	1.0
SO 5.2	Safety	All well used routes in and around building well lit (25%), all routes in and around buildings (25%) visually supervised, secure perimeter and access control (50%), No crime (100%)	90	0.9
SO 5.3	Awareness	% of users who can access information on health & safety issues (ie HIV/AIDS), training and employment opportunities easily (posters/personnel)	50	0.5
SO 5.4	Materials	All materials/components used have no negative effects on indoor air quality (100%)	100	1.0
SO 5.5	Accidents	Method in place for recording all occupational accidents and diseases and addressing these	80	0.8

Building Performance - Economic

	Criteria	Indicative performance measure	Measured	Points
EC 1	**Local economy**			4.2
EC 1.1	Local contractors	% value of the building constructed by local (within 50km) small (employees<20) contractors	80	0.8
EC 1.2	Local materials	% of materials (sand, bricks, blocks, roofing material) sourced from within 50km	80	0.8
EC 1.3	Local components	% of components (windows, doors etc) made locally (in the country)	90	0.9
EC 1.4	Local furniture/fittings	% of furniture and fittings made locally (in the country)	80	0.8
EC 1.5	Maintenance	% of maintenance and repairs by value that can, and are undertaken, by local contractors (within 50km)	90	0.9
EC 2	**Efficiency**			4.3
EC 2.1	Capacity	% capacity of building used on a daily basis (actual number of users / number of users at full capacity*100)	90	0.9
EC 2.2	Occupancy	% of time building is occupied and used (actual average number of hours used / all potential hours building could be used (24) *100)	80	0.8
EC 2.3	Space per occupant	Space provision per user not more than 10% above national average for building type (100%)	80	0.8
EC 2.4	Communication	Site/building has access to internet and telephone (100%), telephone only (50%)	100	1.0
EC 2.5	Material & Components	Building design coordinated with material / component sizes in order to minimise wastage. Walls (50%), Roof and floors (50%)	80	0.8
EC 3	**Adaptability**			3.7
EC 3.1	Vertical heights	% of spaces that have a floor to ceiling height of 3000mm or more	100	1.0
EC 3.2	External space	Design facilitates flexible external space use (100%)	100	1.0
EC 3.3	Internal partition	Non loadbearing internal partitions that can be easily adapted (loose partioning (100%), studwall (50%), masonary (25%)	25	0.3
EC 3.4	Modular planning	Building with modular stucture, envelope (fenestration) & services allowing easly internal adaptaptation (100%)	60	0.6
EC 3.5	Furniture	Modular, limited variety furniture - can be easily configured for different uses (100%)	80	0.8
EC 4	**Ongoing costs**			3.4
EC 4.1	Induction	All new users receive induction training on building systems (50%), Detailed building user manual (50%)	0	0.0
EC4.2	Consumption & waste	% of users exposed on a monthly basis to building performance figures (water (25%), electricity (25%), waste (25%), accidents (25%)	50	0.5
EC 4.2	Metering	Easily monitored localised metering system for water (25%) and energy (75%)	100	1.0
EC4.3	Maintenance & Cleaning	Building can be cleaned and maintained easily and safely using simple equipment and local non-hazardous materials (100%)	100	1.0
SO 4.5	Procurement	% of value of all materials/equipment used in the building on a daily basis supplied by local (within the country) manufacturers	90	0.9
EC 5	**Capital Costs**			4.1
EC 5.1	Local need	Five percent capital cost allocated to address urgent local issues (employment, training etc) during construction process (100%)	90	0.9
EC5.2	Procurement	Tender / construction packaged to ensure involvement of small local contractors/manufacturers (100%)	90	0.9
EC 5.3	Building costs	Capital cost not more than fifteen % above national average building costs for the building type (100%)	80	0.8
EC5.4	Sustainable technology	3% or more of capital costs allocated to new sustainable/indigenous technology (100%)	80	0.8
EC 5.5	Existing Buildings	Existing buildings reused (100%)	70	0.7

Building Performance - Environmental

	Criteria	Indicative performance measure	Measured	Points
EN 1	**Water**			4.3
EN 1.1	Rainwater	% of water consumed sourced from rainwater harvested on site	50	0.5
EN 1.2	Water use	% of equipment (taps, washing machines, urinals showerheads) that are water efficient	100	1.0
EN 1.3	Runoff	% of carparking, paths, roads and roofs that have absorbant/permeable surfaces (grassed/thatched/looselaid paving/ absorbant materials)	100	1.0
EN 1.4	Greywater	% of water from washing/relatively clean processes recycled and reused	100	1.0
EN 1.5	Planting	% of planting (other than food gardens) on site with low / appropriate water requirements	80	0.8
EN 2	**Energy**			2.9
EN 2.1	Location	% of users who walk / use public transport to commute to the building	50	0.5
EN 2.2	Ventilation	% of building ventilation requirements met through natural / passive ventilation	70	0.7
EN 2.3	Heating & Cooling	% of occupied space which has passive environmental control (no or minimal energy consumption)	70	0.7
EN 2.4	Appliances & fittings	% of appliances / lighting fixtures that are classed as highly energy efficient (ie energy star rating)	80	0.8
EN 2.5	Renewable energy	% of building energy requirements met from renewable sources	20	0.2
EN 3	**Waste**			2.4
EN 3.1	Toxic waste	% of toxic waste (batteries, ink cartridges, flourescent lamps) recycled	100	1.0
EN 3.2	Organic waste	% of organic waste recycled	50	0.5
EN 3.3	Inorganic waste	% of inorganic waste recycled.	80	0.8
EN 3.4	Sewerage	% of sewerage recycled on site	0	0.0
EN 3.5	Construction waste	% of damaged building materials / waste developed in construction recycled on site	10	0.1
EN 4	**Site**			2.3
EN 4.1	Brownfield site	% of proposed site already disturbed / brownfield (previously developed)	0	0.0
EN 4.2	Neighbouring buildings	No neighbouring buildings negatively affected (access to sunlight, daylight, ventilation) (100%)	100	1.0
EN 4.3	Vegetation	% of area of area covered in vegetation (include green roofs, internal planting) relative to whole site	50	0.5
EN 4.4	Food gardens	Food gardens on site (100%)	0	0.0
EN 4.5	Landscape inputs	% of landscape that does not require mechanical equipment (ie lawn cutting) and or artificial inputs such as weed killers and pesticides	80	0.8
EN 5	**Materials & Components**			2.2
EN 5.1	Embodied energy	Materials with high embodied energy (aluminium,plastics) make up less than 1% of weight of building (100%)	50	0.5
EN 5.2	Material sources	% of materials and components by volume from grown sources (animal/plant)	5	0.1
EN 5.3	Ozone depletion	No materials and components used requiring ozone depleting processes (100%)	60	0.6
EN 5.4	Recyled / reuse	% of materials and components (by weight) reused / from recycled sources	20	0.2
EN 5.5	Construction process	Volume / area of site disturbed during construction less than 2X volume/area of new building (100%)	80	0.8