7

Technical Investigation

7
TECHNICAL INVESTIGATION

7.1 STRUCTURE

The main structural system used in the design and conceptualisation of the proposed intervention, is a concrete column and slab structure. Because of the subterranean character of the design it was felt appropriate to make use of a material that offers unparalleled structural integrity and durability (Cement and Concrete Institute, 2009).

Throughout the design, concrete is utilised both to provide the permanent grid infrastructure for the overall complex as well as most of the infill elements within the museum building.

Within the parking garage, a steel reinforced concrete coffer-slab construction was chosen. In keeping with the concept of *the punch* and the *the surface*, the texture and recesses of the coffers, enhanced the conceptual thinking behind the design. This method of construction was also preferred because of its aesthetic appeal as well as the various benefits in terms of structural robustness and economic use of material. The slab construction within the museum building itself is a steel reinforced concrete flat slab with an off-shutter finish. This decision was made because the design called for a shift in materiality to signal a change in the spatial configuration and programme.

The column grid used in the design is determined by the parking layout. This grid subsequently guides the spatial configuration of the museum and landscaped elements, as well as the treatment of surfaces and placement of architectural and design elements.

The columns are 300mm x 600mm in size and spaced on a 7800mm x 8100mm/9900mm grid, with a floor to soffit height of 3570mm. The flat and coffer slabs are 400mm thick, with the coffers sized at 900mm x 900mm with a 225mm depth.

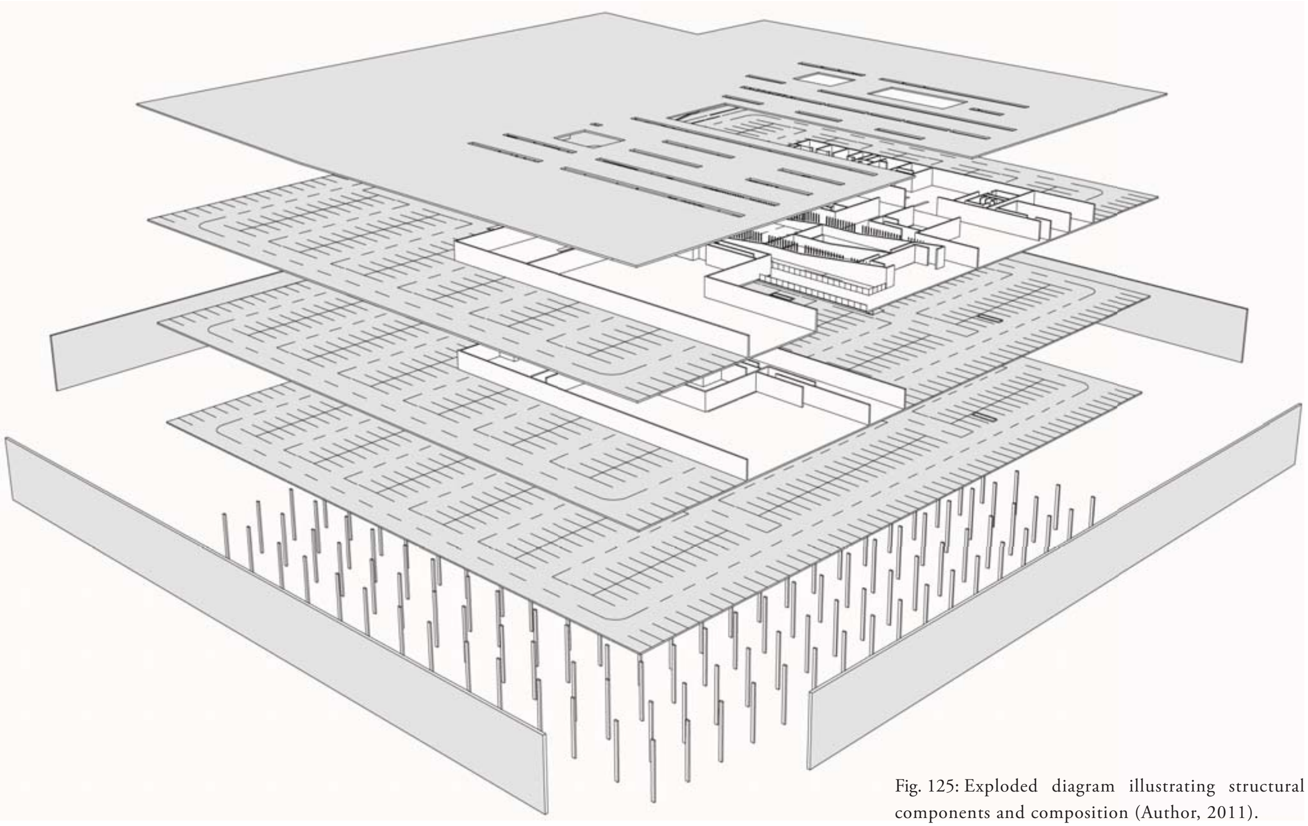


Fig. 125: Exploded diagram illustrating structural components and composition (Author, 2011).

7.2 ROOF CONSTRUCTION

The design of the museum was conceived of as an anti-volume, an architecture that has no physical outward volumetric expression. The architecture submerges itself within the ground and acts as a platform that supports the landscape - the roof of the building becomes the surface of the public square.

Similar to the rest of the building, the roof of the museum and parking garage is steel reinforced concrete. The exterior of the roof becomes the public square which has the reinforced concrete as support structure, but is mainly finished in granite tiles that are supported on polypropylene pedestals. The tiles are 1000mm x 600mm in size with 5mm spacing. Together with the granite tiles, composite EcoDecking is installed on an aluminium joist system, also supported on the pedestals. Because the system is elevated 200mm above the concrete roof, it allows for the waterproofing, insulation and stormwater management to be concealed, resulting in a seamless and unobtrusive construction.

Within the roof structure there are various openings that are articulated as skylights on the interior of the museum, allowing for daylight to flood these spaces. The skylights also provide a connection between inside and outside, heightening the individual's perception of what happens above and below. The concept of linearity is also strengthened by means of linear light-lines on the exterior surface of the square. These recessed lighting elements emulate the positioning of the skylights and provide for dramatic lighting at night.

In certain places the roof also gives way to form courtyards that are accessible from the museum. The courtyards are viewed as depressed planes within the uniform surface of the square and alludes to the presence of the museum underfoot.

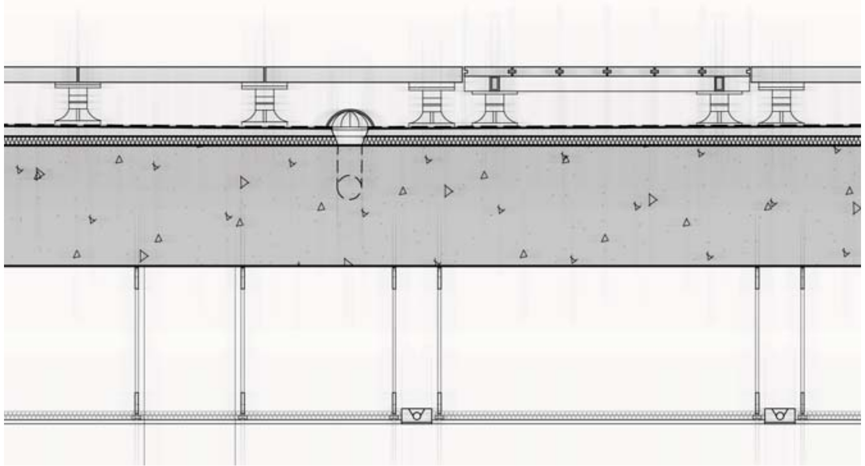


Fig. 127: Roof construction. Scale 1:25 (Author, 2011).

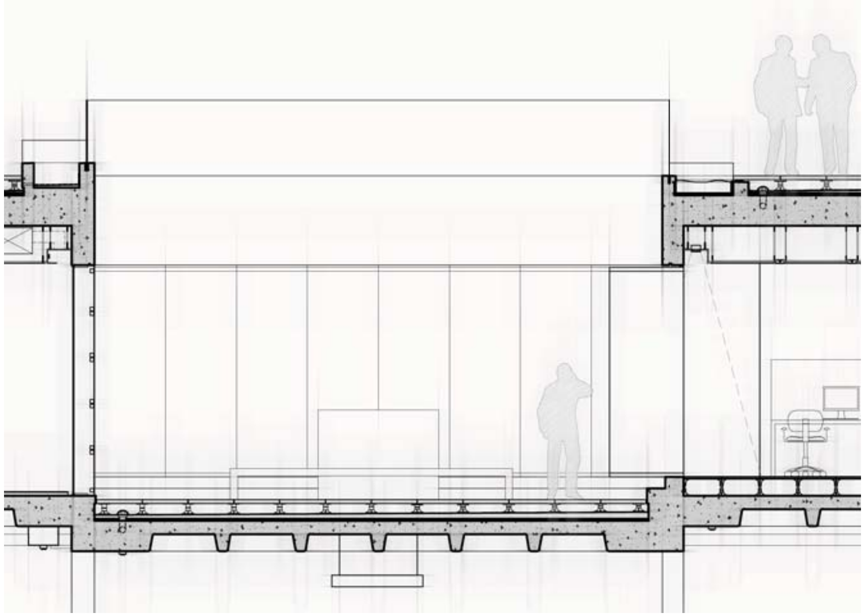


Fig. 126: Courtyard construction and spatial relationship. Scale 1:100 (Author, 2011).

7.3 SERVICES

In order to manage and fulfill the functional requirements of the programme, various methods and systems have to be employed. These systems include thermal comfort and climate control, circulation, lighting, water and waste management and ventilation.

7.3.1 THERMAL COMFORT

Due to the stereotomic character of the structure, it has a very high thermal mass (Green building council of Australia, 2005: 40). The thermal mass provided by the reinforced concrete construction is utilised to regulate the internal thermal conditions of the museum and parking basement.

The heavy mass of the roof construction is able to absorb direct and indirect solar radiation in the summer and retain it for a sufficient amount of time before reradiating it to the interior spaces. The stored heat only reaches the interior of the building at night time, ensuring a cool building by day and a warmer building by night. A mechanical ventilation strategy is implemented where the interior is ventilated to get rid of excessive heat during the summer evenings. During winter, the spaces will not be ventilated at night, in order to retain the reradiated heat. Additional insulation is provided by the raised floor construction of the square by means of the inherent air gap and other conventional insulation materials.

With the building being earth sheltered, the temperature fluctuations of the building mass is also tempered and kept constant. Ground temperatures below 500mm are extremely stable, even if external temperatures fluctuate greatly (Green building council of Australia, 2005: 41).

7.3.1.1 SOLAR CONTROL

As discussed, the thermal mass of the building keeps the ambient temperatures of the internal spaces very comfortable. Throughout the structure there are however various glazing elements that compromise the effectiveness of the thermal massing. These elements take the form of skylights as well as floor to ceiling glazed walls in the courtyard spaces.

The glazing used for the construction of the skylights is a high-performance thermal glazing known as Sunergy®. This glazing has the best thermal performance in its class with a 52% reduction on the solar heat gain when compared to regular float glass (National Glass, 2008: 2).

The skylights will be a double-glazed composite construction which greatly improves the insulating qualities of the unit. To maximise natural daylighting and minimise reflection (without significant loss in insulation and solar heat gain), Sunergy® Neutral glazing is used. The outer leaf of the glazing will be finished with a transparent non-slip coating seeing as they will be located within a highly trafficable area.

To aid in the diffusion of light and to emphasise their linearity, the skylight cavities are fitted with white pigmented glass reinforced concrete fins.

The glazed walls found in the courtyard spaces also pose a challenge in terms of solar control. In order to manage solar exposure on these walls, a solar screen structure is implemented on the exterior of the glazing. This screen sufficiently reduces solar heat gain on the western and eastern facing walls, whilst retaining a visual connection with the exterior.

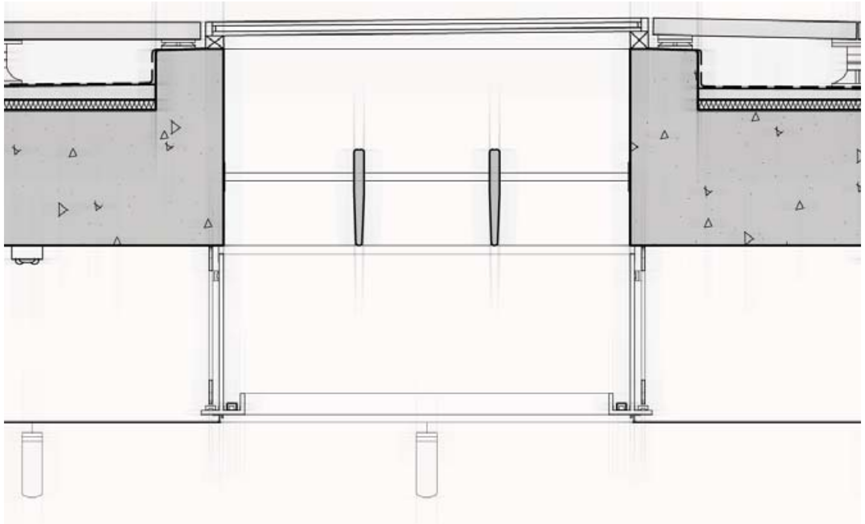


Fig. 128: Skylight detailing and construction. Scale 1:25 (Author, 2011).

7.3.2 VENTILATION

7.3.2.1 MUSEUM BUILDING

Because the museum development is entirely located underground, it makes it impractical to naturally ventilate the museum building itself. The building is entirely reliant on mechanical ventilation as well as mechanical heating and cooling. Fresh air is taken in from the exterior of the square. Vertical air-inlets were not feasible within the design, so air is taken in from the surface of the square. These inlets are integrated with seating elements that border the formal section of the public space and will be fitted with the necessary filters to accommodate for the surface air intake. The exhaust air is extracted to the basement parking structure from where it is allowed to escape to the surface.

Air handling and HVAC within the museum building, is dealt with by means of two plant rooms. The plant rooms are strategically placed in order to serve the two wings of the museum respectively.

7.3.2.2 PARKING STRUCTURE

The parking structure is also located completely underground which makes the ventilation of this structure equally challenging. On two walls of the basement (the sides bordering Visagie and Minnaar Streets) the floor slabs are pulled away from the retaining walls to allow for a 1000mm opening stretching over the three floors to the exterior. The openings allow for natural light to enter the cavernous spaces as well as for the movement of air in, through and out of the structure.

The circulation of air within the basement is aided by mechanical ventilation which also relies on fresh air intake from the square. The air intake is done on the same principle as discussed earlier. A centralised plant room is located within the basement in order to handle the distribution of fresh air to the lower floors. Assisting with the ventilation of the ambient air, is a specialised centrifugal induction fan system. This system allows for a ductless installation that is low in maintenance and very durable, resulting in a more cost-effective operation. Supply and exhaust inlets and fans can also be considerably smaller due to the elimination of air resistance caused by conventional ducting (IAD, 2008). In case of fire, the system also has excellent smoke extraction capabilities and can withstand temperatures of up to 300. The exhaust fans are located within the cavity of the retaining wall construction and allows stale air to be expelled at street level.

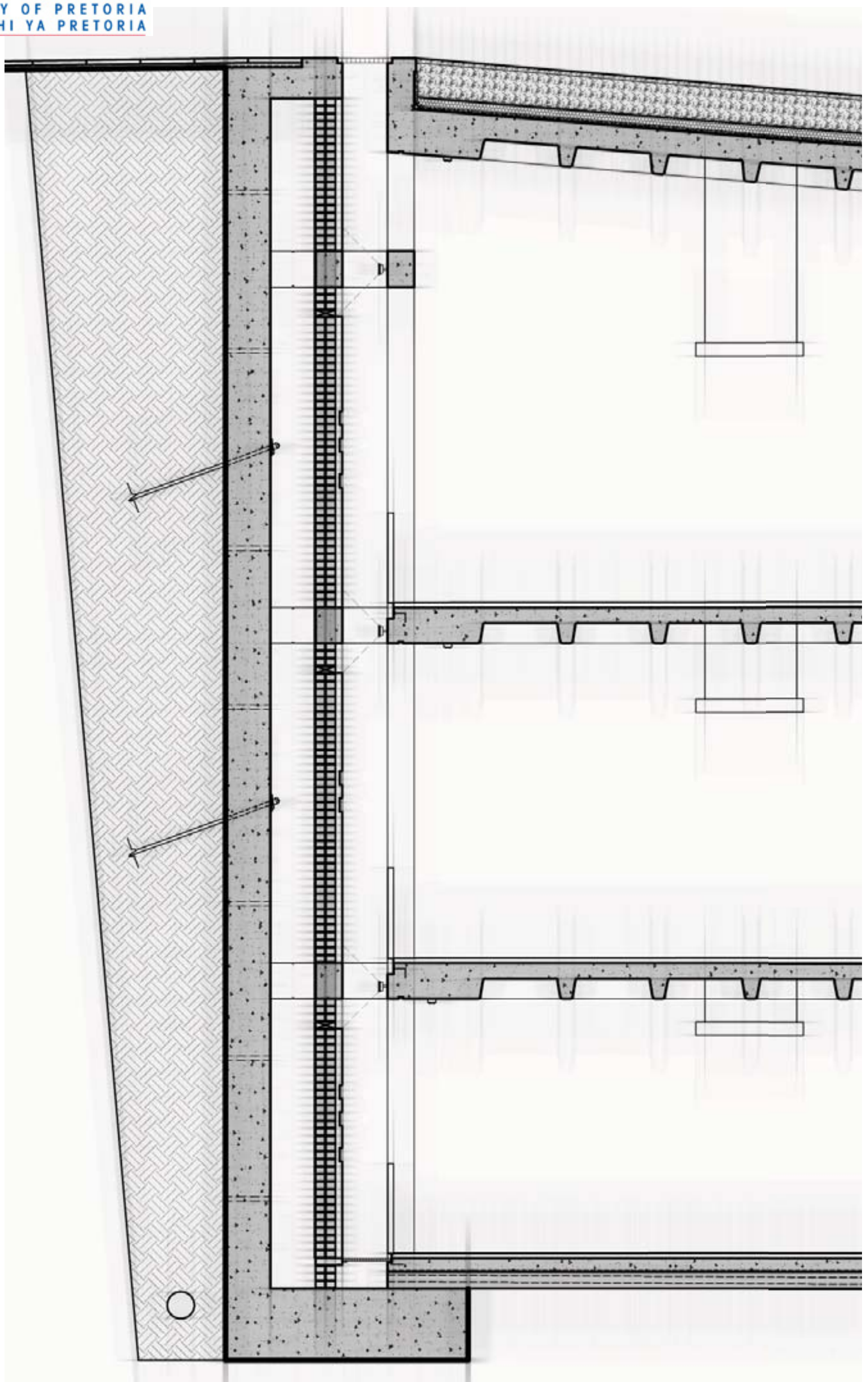


Fig. 129: Basement retaining wall construction and articulation. Scale 1:100 (Author, 2011).

7.3.3 CIRCULATION

Because of the variation in programme, the movement of people differs greatly depending upon the reason for visiting or using the facility.

The everyday commuter travelling along Paul Kruger street will pass the museum building seemingly unnoticed. Only upon crossing the axis between the City Hall and the Museum of Natural History, will the entrance to the museum present itself. The individual can then enter the building or simply continue on their journey. Whilst passing Pretorius square they can also make use of the public facilities at anytime.

The everyday user will mainly utilise the public square which has direct axis from all three bordering street edges. The part of the square that borders Paul Kruger street will be the most frequented, as it was designed to offer a platform for the happening of the everyday urban event.

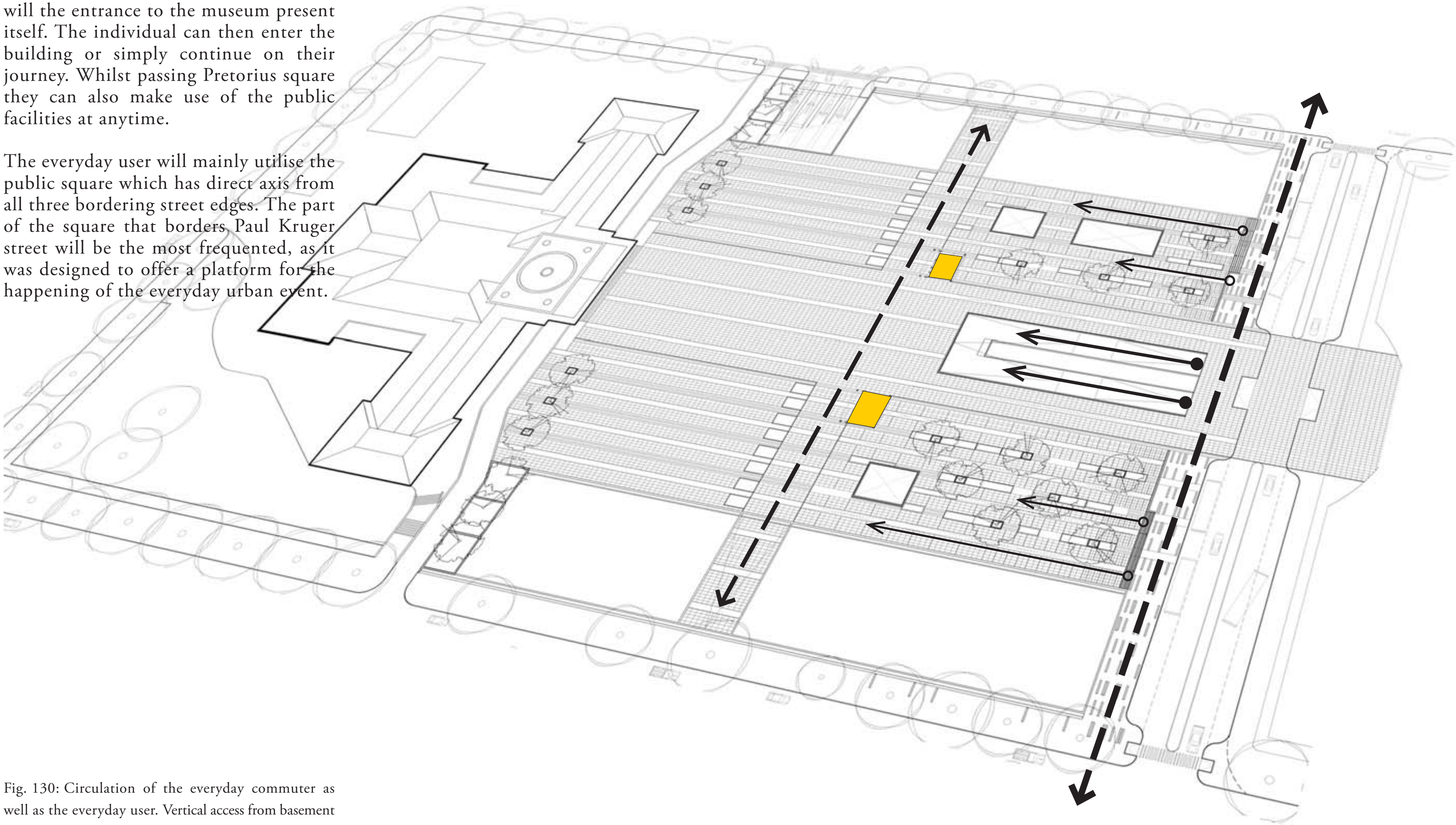


Fig. 130: Circulation of the everyday commuter as well as the everyday user. Vertical access from basement to square in yellow (Author, 2011).

The destination user will have a very different method of circulation compared to either of the two users mentioned above. Upon arrival, the individual will park their car in the underground parking and make their way to the vertical circulation cores (there is no direct access to the museum from the basement parking). Reaching the square, they will be confronted with the presence of City Hall as well as the Museum of Natural History on the Paul Kruger street edge. It is on this edge that they enter the museum building. The ritual of arrival and entering strongly grounds the visitor to context and heightens their awareness of the subterranean nature of the museum intervention.

Entering the museum, the user descends down an entrance ramp and offered glimpses into the interiority of the space as the museum is gradually exposed. Once inside the museum, it becomes evident that the main route of circulation encircles the entrance ramp, offering the user a degree of familiarity and orientation. By having the main circulation route relating to the ceremonial axis predominant on the site, the user is also grounded in space. Branching of from the main circulation loop, are secondary routes with selective pause-spaces to be found along the way.

Access to the lower subterranean floor is gained by means of an additional ramp that also branches of from the circulation ring. On the lower ground floor, individual access to the three galleries is gained from a circulation spine. Once within these galleries, free movement is possible between them without having to return to the main circulation.

The exclusive use of circulation ramps within the design was a conscious decision, as it allows for a greater awareness of the individual's movement through space and time and also ensures complete inclusivity and appropriation by all users.

The articulation of threshold and the emphasis on transition, becomes an intrinsic part of the user experience and the overall spatiality of the museum and the precinct as a whole.

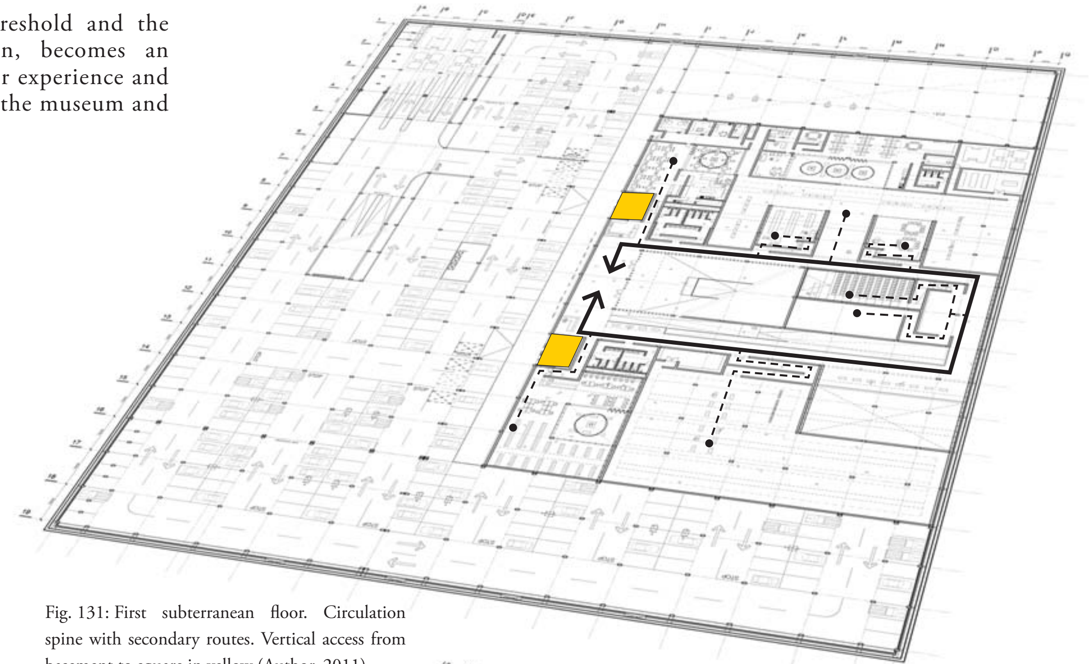


Fig. 131: First subterranean floor. Circulation spine with secondary routes. Vertical access from basement to square in yellow (Author, 2011).

Fig. 132: Second subterranean floor. Circulation ramp with secondary routes. Vertical access from basement to square in yellow (Author, 2011).

7.3.4 LIGHTING

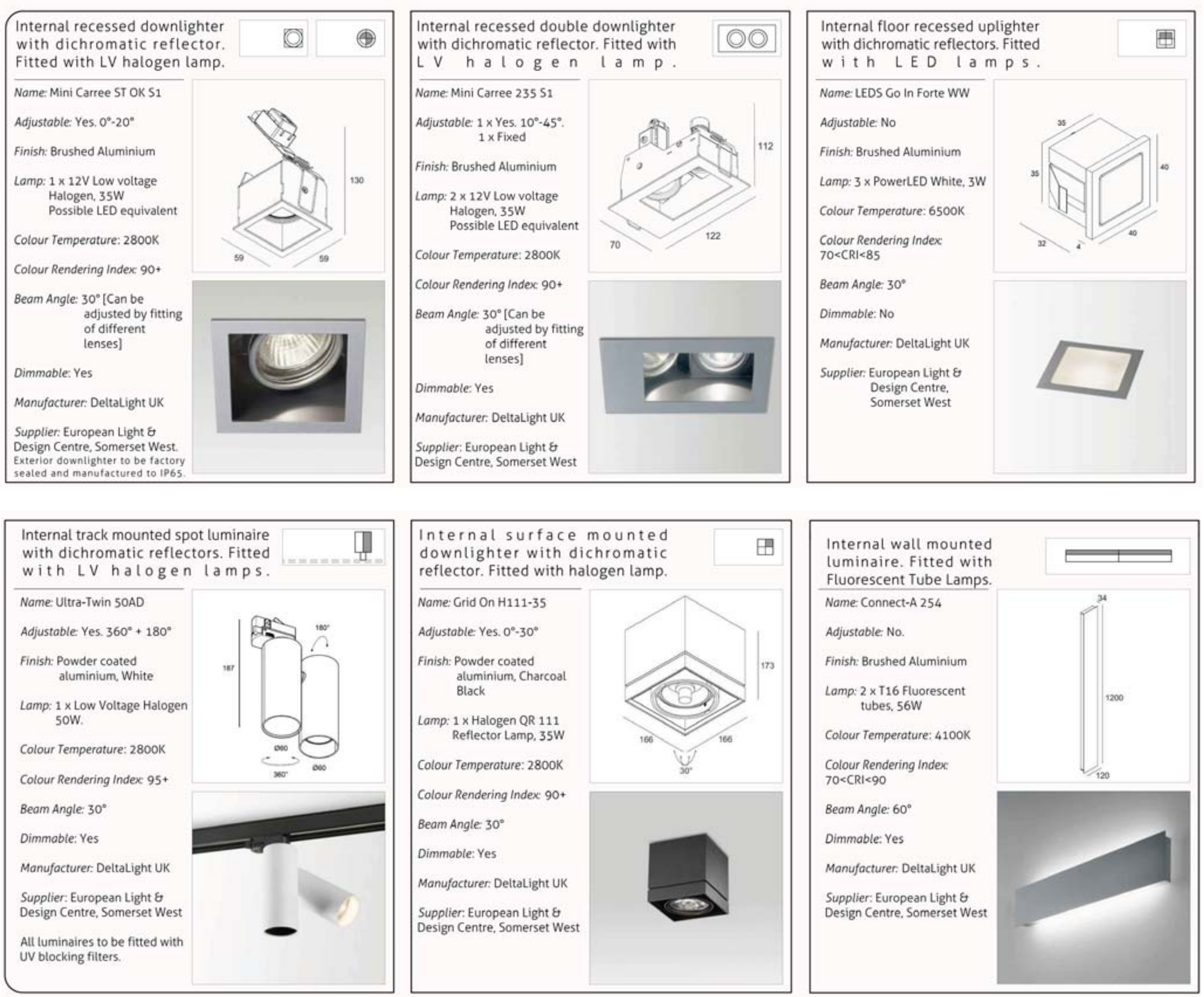
The lighting systems in the facility is of utmost importance. Natural light is utilised where possible, but because of the cavernous museum spaces, artificial lighting will be necessary throughout.

When working with artificial light, there are two key elements to keep in consideration. Firstly, the colour rendering index (CRI) of the lamps and secondly the colour temperature (CT). For general lighting and tasks, a CRI of between 70 and 90 is desirable. In the case of gallery spaces, where the correct reproduction of colour and texture is pivotal, a CRI of 90+ is neccesary (Krüger, 2011).

Throughout the design, different variation of white light will be used. Both warm white (CT = 2800K) and cool white (CT = 4000K) lamps will be employed depending on the space and the desired effect. Together with the colour temperature, the effects of diffused, direct and indirect lighting was also be investigated.

To keep the environmental impact to a minimum, commercial LED and CFL lamps will be used throughout. Where there is a need for exceptional colour rendering however, halogen incandescent lamps or high-end LED or CFL lamps will be used (Krüger, 2011).

Because of the complex and highly specialised nature of architectural lighting installations, the expertise of a lighting design company is of utmost importance.



Internal recessed downlighter with dichromatic reflector. Fitted with LV halogen lamp.

Name: Mini Carree ST OK S1

Adjustable: Yes. 0°-20°

Finish: Brushed Aluminium

Lamp: 1 x 12V Low voltage Halogen, 35W
Possible LED equivalent

Colour Temperature: 2800K

Colour Rendering Index: 90+

Beam Angle: 30° [Can be adjusted by fitting of different lenses]

Dimmable: Yes

Manufacturer: DeltaLight UK

Supplier: European Light & Design Centre, Somerset West.
Exterior downlighter to be factory sealed and manufactured to IP65.

Internal recessed double downlighter with dichromatic reflector. Fitted with LV halogen lamp.

Name: Mini Carree 235 S1

Adjustable: 1 x Yes. 10°-45°.
1 x Fixed

Finish: Brushed Aluminium

Lamp: 2 x 12V Low voltage Halogen, 35W
Possible LED equivalent

Colour Temperature: 2800K

Colour Rendering Index: 90+

Beam Angle: 30° [Can be adjusted by fitting of different lenses]

Dimmable: Yes

Manufacturer: DeltaLight UK

Supplier: European Light & Design Centre, Somerset West

Internal floor recessed uplighter with dichromatic reflectors. Fitted with LED lamps.

Name: LEDS Go In Forte WW

Adjustable: No

Finish: Brushed Aluminium

Lamp: 3 x PowerLED White, 3W

Colour Temperature: 6500K

Colour Rendering Index: 70<CRI<85

Beam Angle: 30°

Dimmable: No

Manufacturer: DeltaLight UK

Supplier: European Light & Design Centre, Somerset West

Internal track mounted spot luminaire with dichromatic reflectors. Fitted with LV halogen lamps.

Name: Ultra-Twin 50AD

Adjustable: Yes. 360° + 180°

Finish: Powder coated aluminium, White

Lamp: 1 x Low Voltage Halogen 50W.

Colour Temperature: 2800K

Colour Rendering Index: 95+

Beam Angle: 30°

Dimmable: Yes

Manufacturer: DeltaLight UK

Supplier: European Light & Design Centre, Somerset West

All luminaires to be fitted with UV blocking filters.

Internal surface mounted downlighter with dichromatic reflector. Fitted with halogen lamp.

Name: Grid On H111-35

Adjustable: Yes. 0°-30°

Finish: Powder coated aluminium, Charcoal Black

Lamp: 1 x Halogen QR 111 Reflector Lamp, 35W

Colour Temperature: 2800K

Colour Rendering Index: 90+

Beam Angle: 30°

Dimmable: Yes

Manufacturer: DeltaLight UK

Supplier: European Light & Design Centre, Somerset West

Internal wall mounted luminaire. Fitted with Fluorescent Tube Lamps.

Name: Connect-A 254

Adjustable: No.

Finish: Brushed Aluminium

Lamp: 2 x T16 Fluorescent tubes, 56W

Colour Temperature: 4100K

Colour Rendering Index: 70<CRI<90

Beam Angle: 60°

Dimmable: Yes

Manufacturer: DeltaLight UK

Supplier: European Light & Design Centre, Somerset West

Fig. 133: Exploration of possible luminaires to be incorporated into the design (Author, 2011).

7.3.5 WATER MANAGEMENT

The water management of the proposal proved challenging due to the subterranean nature of the project.

7.3.5.1 BASEMENT CONSTRUCTION

It was decided to employ a cavity construction for the basement structure. This approach was chosen due to the various advantages it offers over a tanked basement construction (Wegelin, 2006: 1.33). Cavity construction allows for the ingress of groundwater through the retaining wall by keeping the ferrule holes exposed and unblocked. Groundwater is then drained into sumps from where it is pumped to the municipal stormwater connection.

7.3.5.2 RAINWATER MANAGEMENT

The majority of the landscaping on the redesigned square is comprised of hard surfaces which makes stormwater management very important. The raised floor construction of the square allows for water to seep through the granite tiles by means of the 5mm jointing gaps that are incorporated into the layout.

Once the rainwater enters the floor cavity it is dealt with in the conventional manner. Rainwater outlets are cast into the concrete roof construction which allow the water to drain from the square into the municipal stormwater system.

Where the municipal connection is higher than the points of drainage, the rainwater is drained into the basement sumps from where it is then pumped to the stormwater connection. The various planters on the square also drain into this floor/roof cavity.

Where it is not possible for rainwater to drain into the raised flooring of the square, stormwater catchment channels are utilised. Stormwater channels are also integrated into the vehicle ramps in order to minimise rainwater accumulation in the basement.

7.3.5.3 SEWAGE MANAGEMENT

The sewage management of the museum proved challenging due to the design of the building. Because the structure is positioned below ground, it makes it difficult to directly dispose of the sewage via the municipal connection. A sewage holding tank system, where the waste is temporarily stored on site, will thus have to be installed.

In order to determine the sizing of the holding tanks required, the amount of waste that is produced will have to be calculated. It has to be mentioned that it is both black and grey water that will be stored on site.

With a holding tank system it is of utmost importance to minimise daily sewage flow. All fittings will thus be water efficient and operated through Infra-Red sensors. WCs will be dual-flush, using a minimum of 3ltrs of water and a maximum of 8ltrs per flush.

If assumed that there are 25 permanent staff members, who each flush the WC a maximum of 4 times during an 8 hour shift, then:

25 x 4 = 100 flushes per day

The museum can also expect an average of 300 visitors per day:

300 x 1flush = 300 flushes per day

Taken that the WCs consume a maximum of 8ltrs of water per flush it can be calculated that the facility will produce:

(100 + 300) x 8ltrs = 4000ltrs of
black waste water per day

The basins consume 1,9ltrs of water per minute of operation and the average person uses a basin for 15secs.

1,9ltrs / 4 = 0.5ltrs per use

If a basins is used every time a WC is flushed then:

(100 + 300) x 0,5ltrs = 200ltrs of
grey waste water per day

The total daily sewage flow (DSF) is thus:

= 3200 + 200 = 3400ltrs per day

Assuming that the sewage will be pumped up to the municipal connection every other day, the normal operating volume (NOV) of the museum will be

= 3400 x 2 = 6800 ltrs

In case of mechanical pump failure there also has to be a reserve storage volume (RSV) of three times that of the NOV (Department of Health, 2007):

= 6800 x 3 = 20 400 ltrs.

The sizing of the sewage holding tanks are then determined based on the total liquid volume capacity:

= NOV + RSV
3400 + 20 400
23 8004ltrs

The total volume necessary for the successful operation of the system is:

23 800ltrs = 23,8 m^3
= 24 m^3

To accommodate the required volume, 4 interconnected 6m^3 polyethylene sewage storage tanks will be installed. The tanks will be fitted with dual grinder + ejection pumps as well as a sewer force main to be connected to the municipal sewage line.