TECHNICAL RESOLUTION

chapter 6

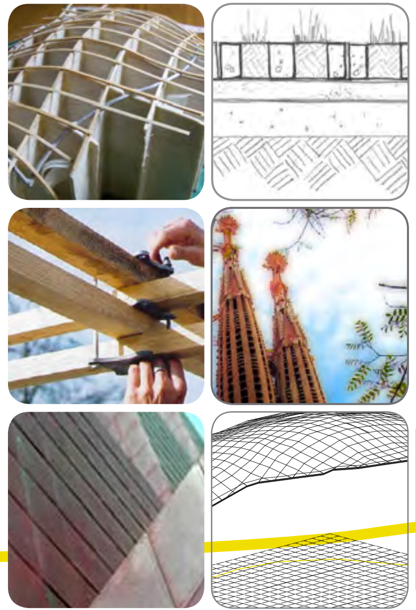
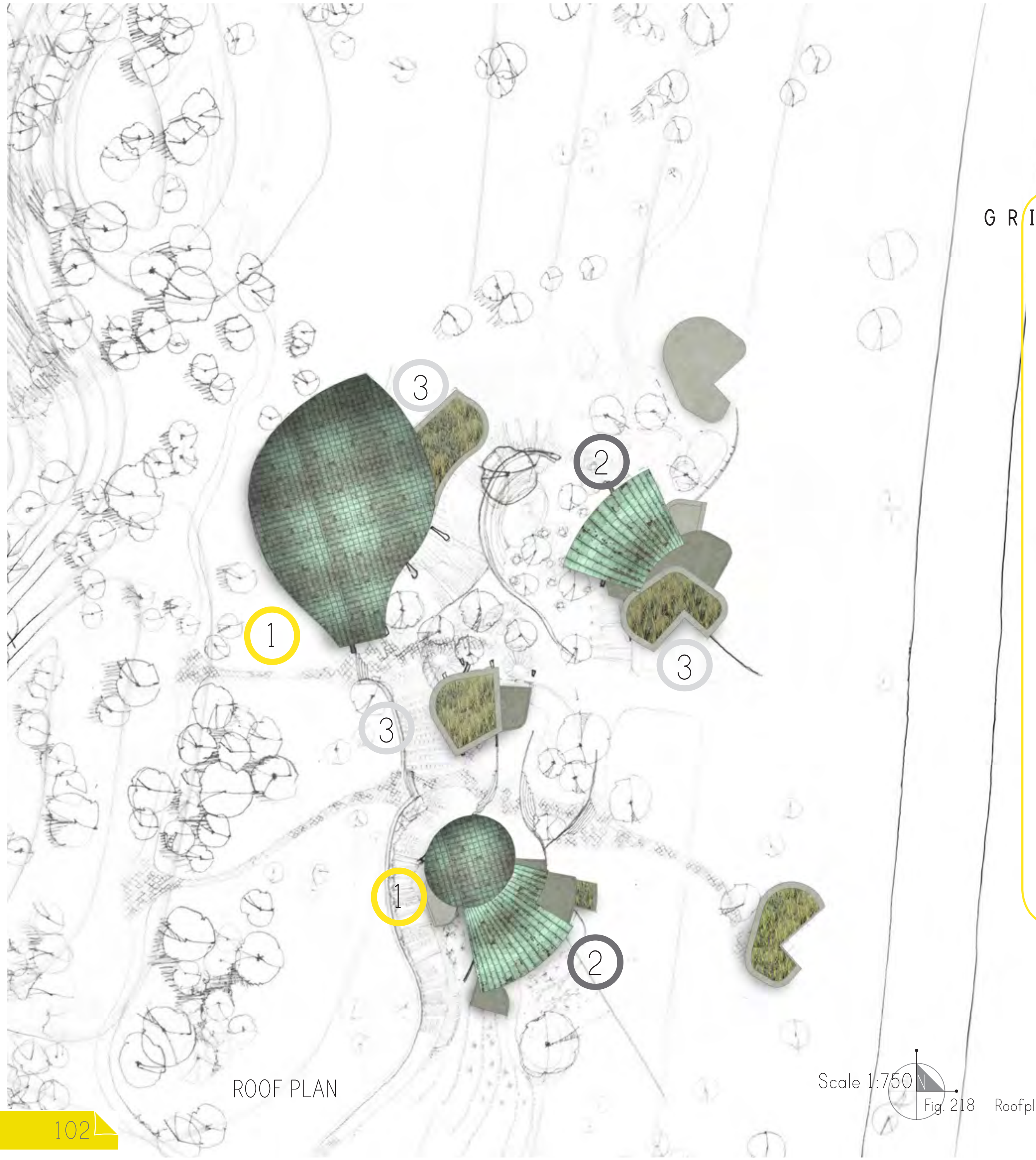


fig. 5.1



ROOF PLAN

Scale 1:750

Fig. 218 Roofplan

GRIDSHELL ROOF SYSTEM

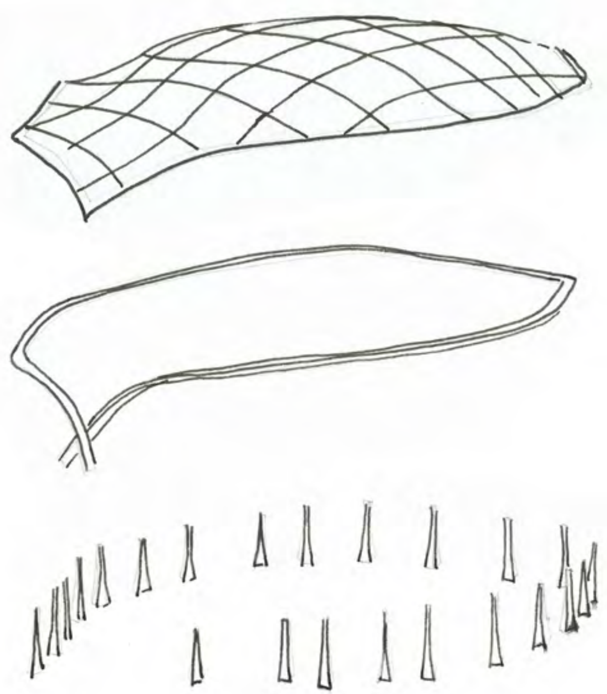
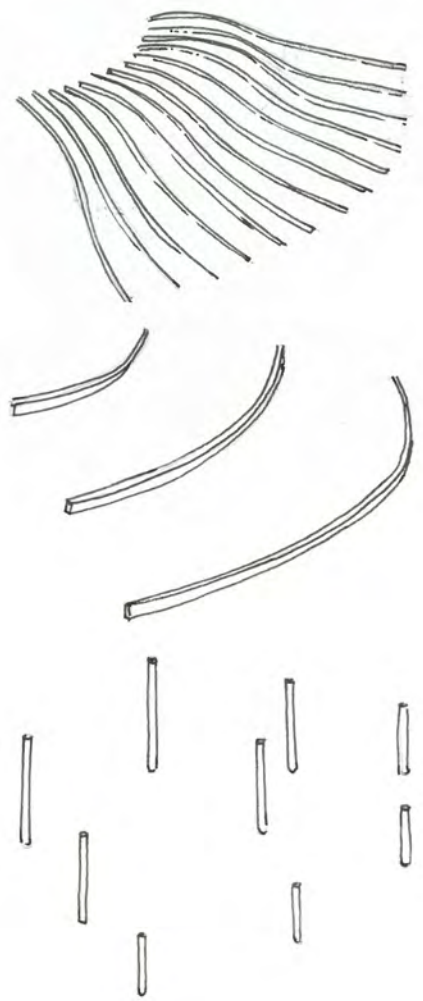


Fig. 219 Gridshell

6.1 STRUCTURAL TYPOLOGIES



GLULAM BEAM SYSTEM

Fig. 220 Beam system

FLATROOF SYSTEM

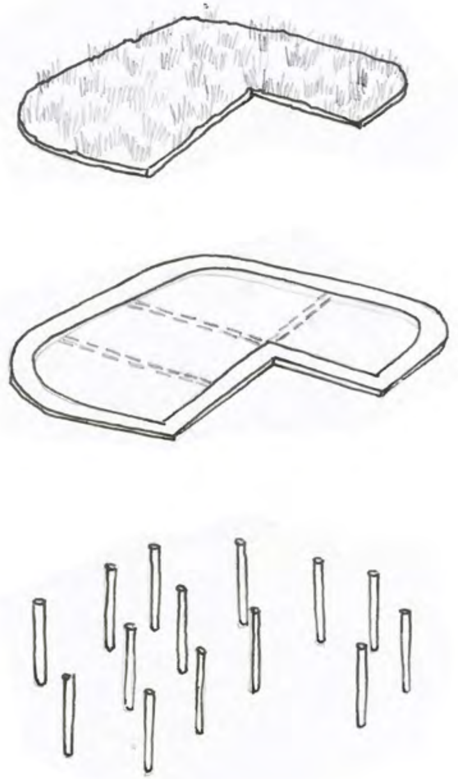
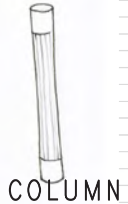
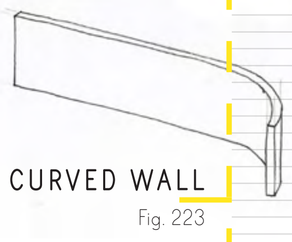


Fig. 221 Flat roof system



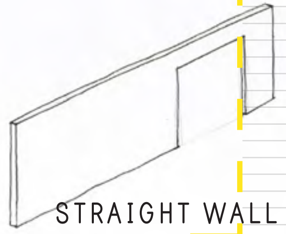
GEOMETRIC COLUMN

Fig. 222



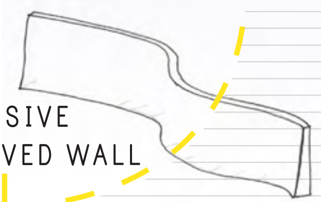
CURVED WALL

Fig. 223



STRAIGHT WALL

Fig. 224



MASSIVE CURVED WALL

Fig. 225

ORANIC COLUMN

Fig. 226

6.2 MATERIAL PALETTE

The precedent selected for the material choice, and specifically the combination of materials is, the NG Universiteitsoord church building by Jan van Wijk. The sculptural quality and rich texture and warmth achieved, displays qualities that are desirable in the Tswaing project. Therefore, the combination of materials were examined as a relevant precedent.

NG kerk Universiteitsoord, Jan van Wijk, 1965
Fig. 227

6.2.1 BRICK

Due to the fact that the natural stone on the site should be preserved and is thus out of bounds as a building material, brick was selected as an alternative. Although man-made, brick inherently tells the story of its creation, as mentioned by Colin St John-Wilson when discussing the work of Alvar Aalto(refer to chapter2). (1992:90) The colour and texture of the brick can also be selected to refer to the context and environment around it.

Brick is suitable to be built along a curve, as is required for the project, even by doing so stabilising freestanding walls.

Fig. 229

Fig. 228

Fig. 231

Fig. 230

6.2.2 TIMBER

Timber laths are laminated with finger and scarf joints, which enables one to cut out the weaker parts of the timber and thus maximise the strength and usability of the lath. This means that local timber may be used instead of importing exotic timber with superior strength qualities. The Saville building is supported by laminated timber lengths of 46m. (annular.org 2006)

FAIR-FACED CONCRETE

Fig. 232

EXPOSED AGGREGATE CONCRETE

Fig. 233

6.2.3 CONCRETE

The organic nature of the built form required the selection of an exceedingly plastic and sculptural material. Rammed earth was considered, but the high slat quality of the earth on the site raised the concern of brittleness. The sculptural ability of the concrete can be increased by adding super plasticizers to the mix. These negate the necessity for vibration, thus the achievable form was less limited.

The variability of concrete was also deemed appropriate to the scheme. The texture can be manipulated by exposing the aggregate, brushing the concrete and by the type of shuttering used. Pigment can be added to change the colour of concrete.

Curves can be achieved with radius wall shuttering. Cost for the shuttering can be maximized by limiting the amount of different radii used in the design.

Adding fly-ash to the concrete offers a more sustainable solution to a product traditionally considered environmentally infriendly.

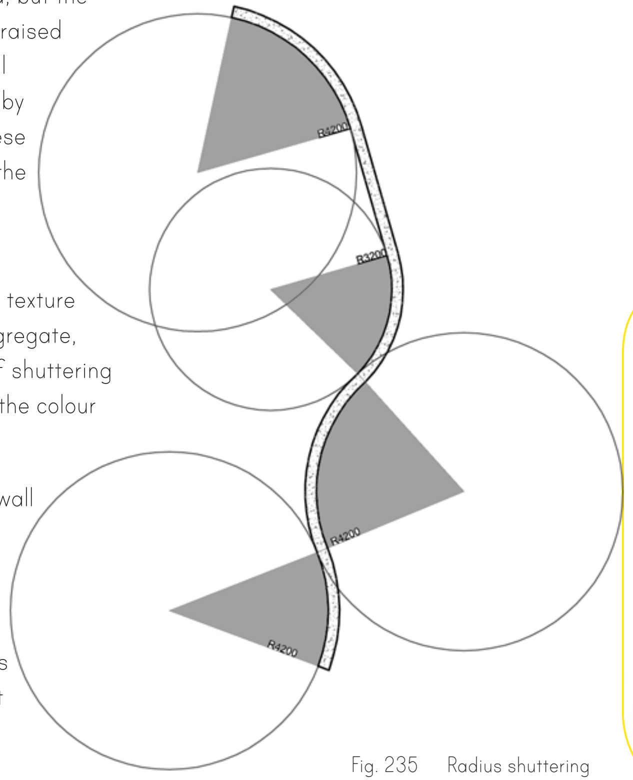


Fig. 235 Radius shuttering

Fig. 234

6.2.4 COPPER

Copper is a natural material that changes its appearance over time. This indicates the connection to the natural environment that is at the core of the project.

The material is well suited to the organic form of the roofs as its pliability allows for different methods of fixing that is adaptable to the shape of the surface.

The visual impact of a copper roof is minimal in a natural landscape as it develops a green patina over time.

Although expensive, it is also a durable material that will last the lifetime of the building with virtually no maintenance needed.

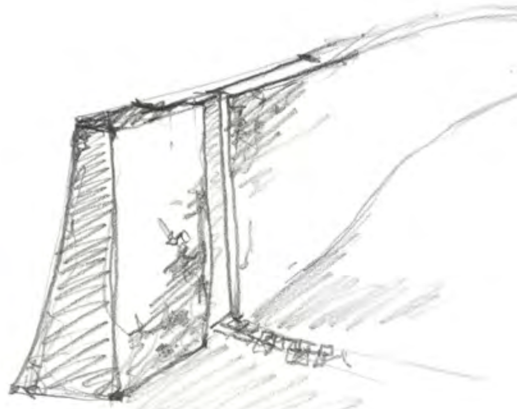


Fig. 236 Concrete wall concept

6.3 GRIDSHELL ROOF

6.3.1 Background

Gridshell roofstructure is a timber lattice that is constructed on a flat plain and then lifted or lowered into the organic shape required. The structure has the ability to span great distances unsupported with the minimal use of material.

In order to generate a structurally sound form, a hanging chain model can be constructed. The hanging chain is an inverted representation of a catenary curve, a structural shape. The chain is in pure tension which translates into pure compression when upturned, dispelling tensile and bending forces. (Graefe 2009: 732) This method of form-finding was used in the past by Antonio Gaudi in buildings such as the the Sagrada Familia, where the organic roof structure was conceived by a complex chain model which was then measured, drawn and directly built. (Graefe 2009:730) Today, some digital aids exist to generate catenary structural forms, that simplify the transmission of the model to workable drawings. This simplifies the process, as a chain model is time consuming to build, difficult to adjust and often inaccurate when translated into reality. (Kilian 2004: 1) The modelling of geometry and physics of the gridshell also minimises the occurrence of breakages in the timber laths. This type of tool being unavailable to the author, the old method of a hanging chain model was built and measured to generate the organic form needed for the scheme.

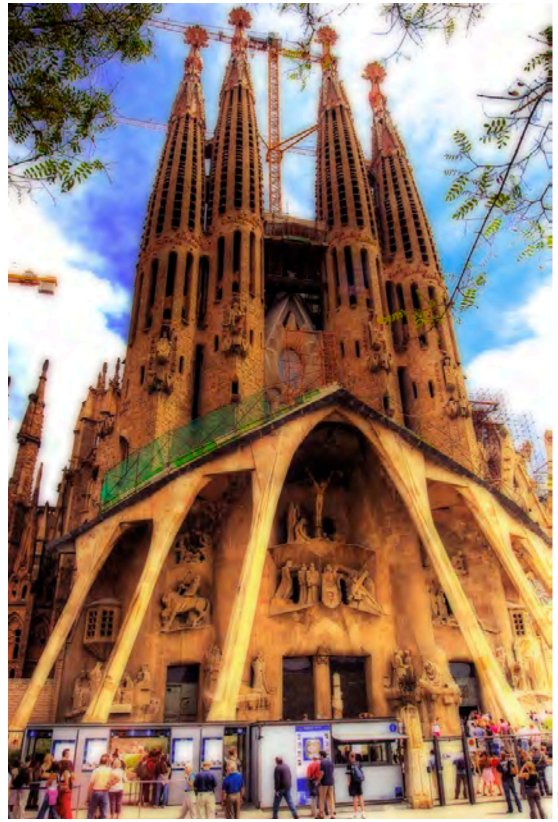


Fig. 237

The form of the Sagrada Familia by Gaudi in Barcelona, was generated by a hanging chain model

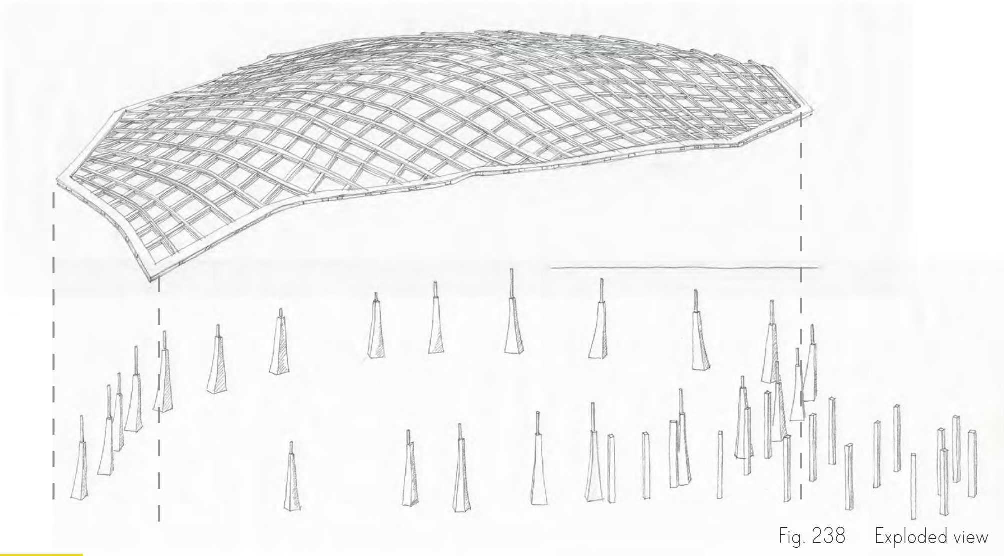


Fig. 238 Exploded view

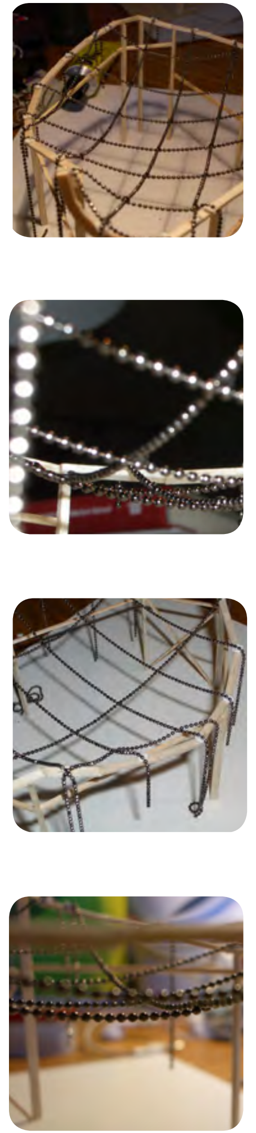


Fig. 239 Hanging chain model

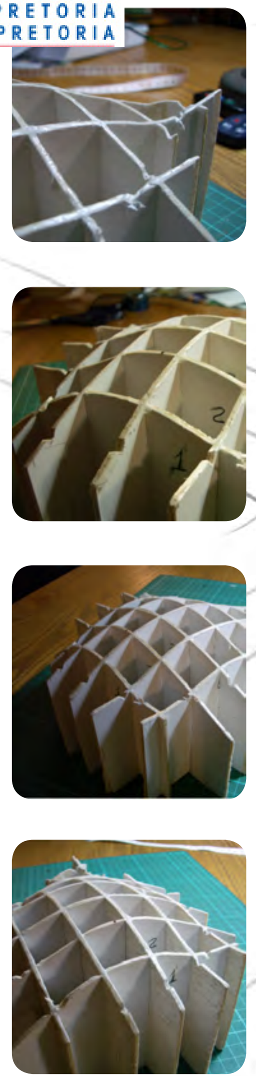
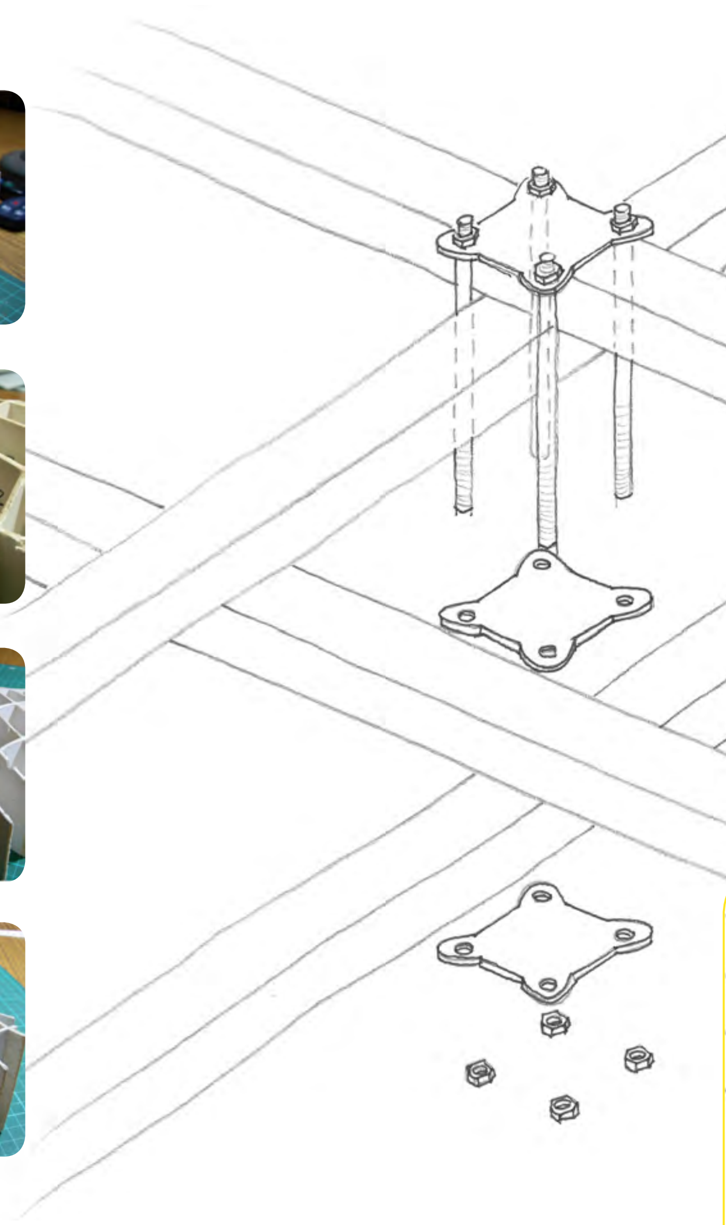


Fig. 240



6.3.2 Laminated timber

The laminated timber laths are layered into a double curvature and connected at the intersections with pinned joints. The connections allow for movement: the grid has the ability to skew into parallelograms to better transfer the load to the edges of the structure. The nodes are clamped by steel plates in between the laths and connected by threaded bolts.

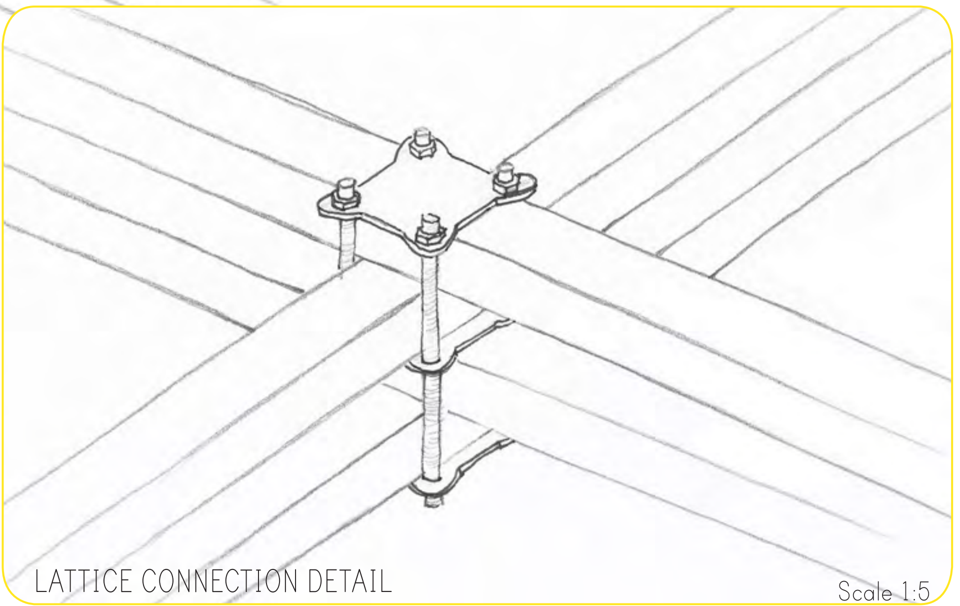
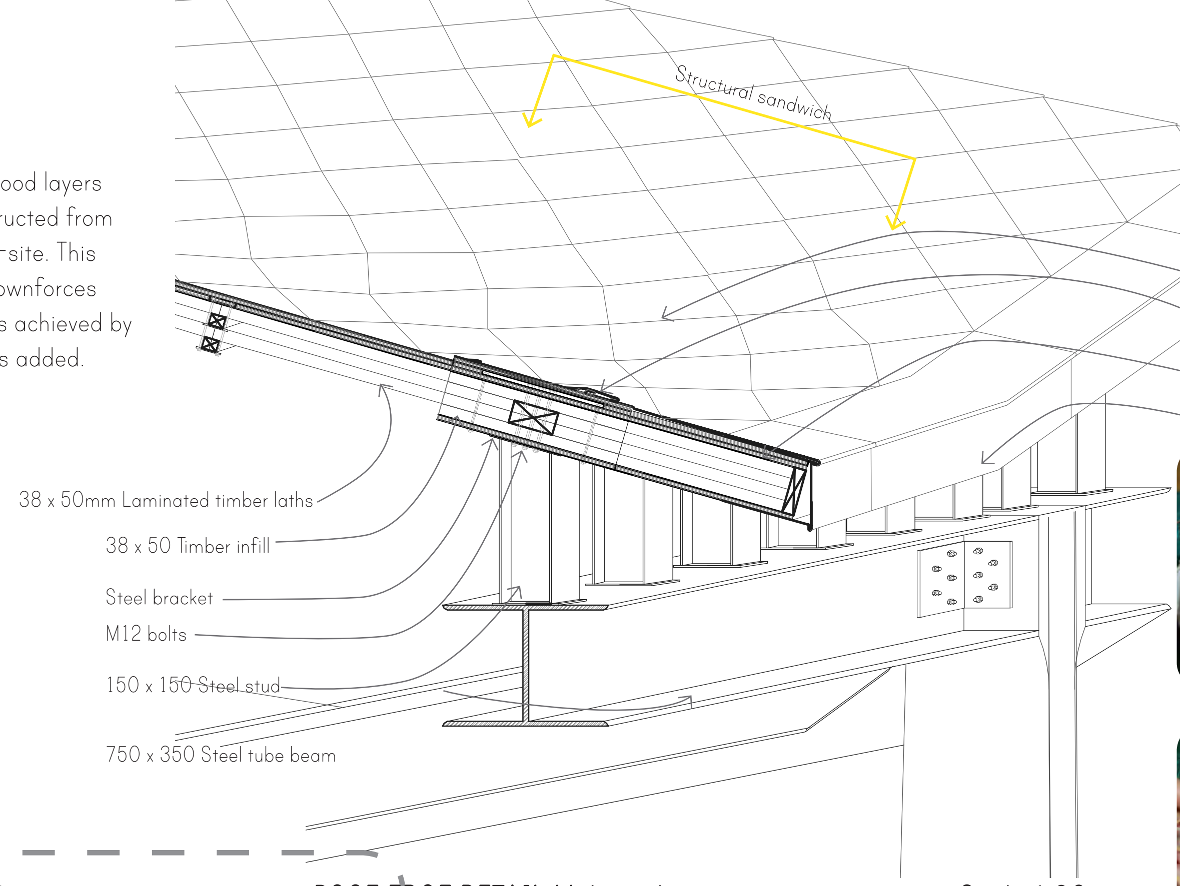


Fig. 241 Lattice connection

6.3.3 Construction

Along the edges the laths are sandwiched between plywood layers and connected to a steel beam. The sizeable beam is constructed from hollow steel sections, factory constructed and connected on-site. This construction absorbs any lateral forces ensuring that only downforces are exercised upon the supporting columns. Further rigidity is achieved by cladding the lattice with plywood before the cover material is added.

The construction process entails the construction of the lattice system on a flat surface, after which the form is achieved by lowering or raising the frame. In the case of the Weald Downland Museum, an adjustable scaffolding system was employed to lower the grid frame into position. The construction of the Mannheim Multihalle however, entailed the grid to be raised with scaffolding towers, hydraulic jacks and forklift trucks. (Orton 1988:440) In this case, the structural supports and non-loadbearing walls will be constructed before the roof, the adjustable scaffolding constructed over the structure and the lattice lowered into place.



ROOF EDGE DETAIL Multimedia experience

Scale 1:20
Fig. 243

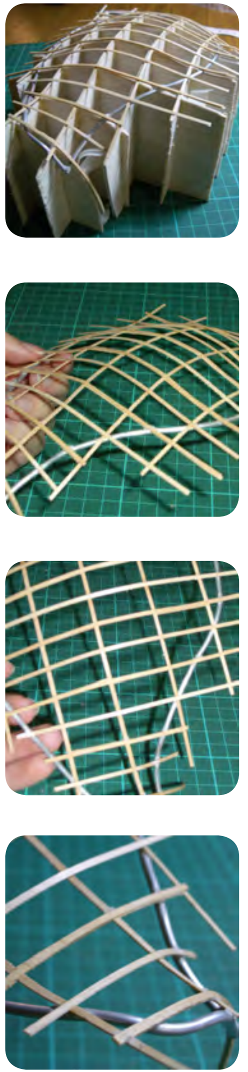
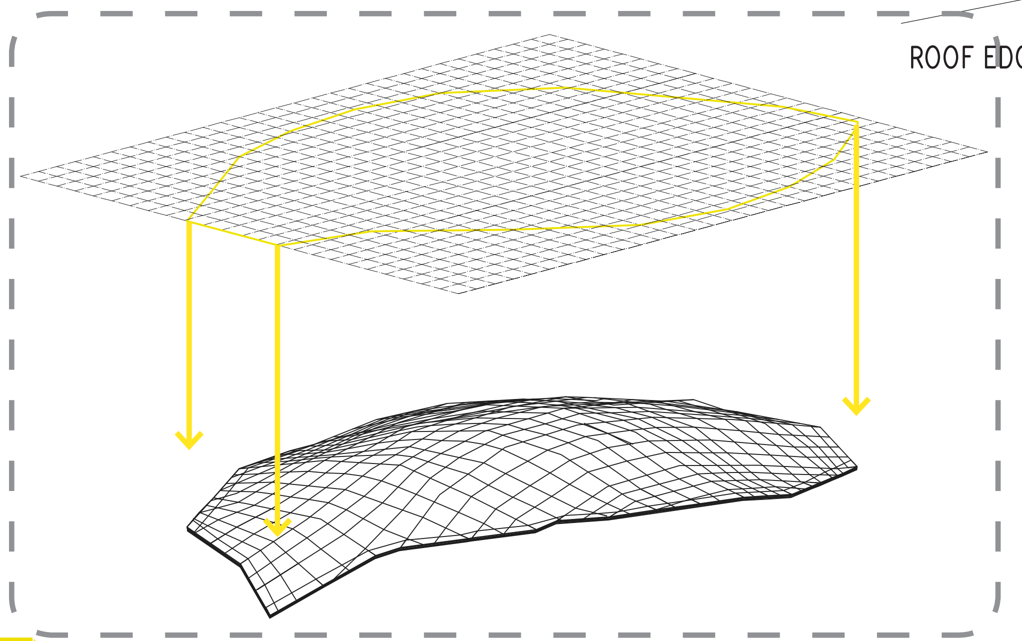


Fig. 244



GRIDSHELL LATTICE LOWERED INTO PLACE

Fig. 242

6.3.4 Precedents

The Mannheim Multihalle, Frei Otto, 1975

The first gridshell structure was designed as a temporary exhibition space for a flower festival in Dorset in South-West England by the German architect-engineer, Frei Otto. It consists of a lightweight structure that spans 60m and is covered by a pvc-coated polyester fabric. Being the first of its kind and built in pre-computer times, the breakages and physical prediction of the form were problems that could be improved on with contemporary computer technology. (Orton 1988:440)

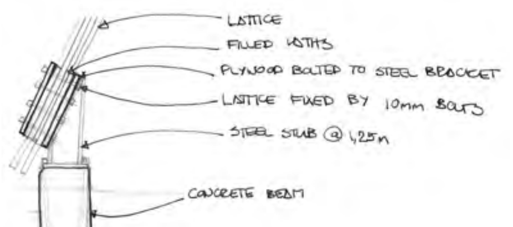


Fig. 245 Detail of Mannheim Multihalle gridshell

Fig. 246 Mannheim Multihalle, Frei Otto, 1975

The Weald Downlands Museum, 2002 and The Savill Building, 2006

The architects of this project, the Edward Cullinan Group, are known for a low environmental impact approach to architecture which is clearly visible in the scheme. The use of local material was later simulated in the Saville building where local timber from the park grounds where the building is located was used for the gridshell roof structure. The Saville Building, designed by the Glen Howells, compares to the Mannheim Multihalle at 90 x 25m and is supported by a steel tube rim. (annular.org 2006) The flatness of the gridshell roof blends into the surrounding landscape, as well as shading the interior and preventing the necessity of artificial cooling.(annular.org 2006)

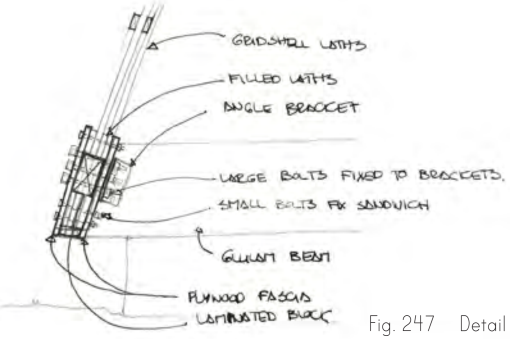


Fig. 247 Detail of Weald and Downlands gridshell

Fig. 248 The Weald and Downlands Museum, 2002

Fig. 249 The Savill Building, Geln Howells Archtects, 2006


Fig. 250


Fig. 251

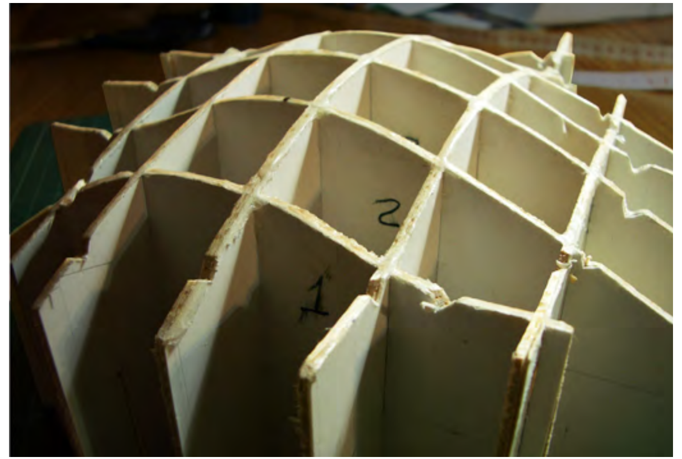


Fig. 253

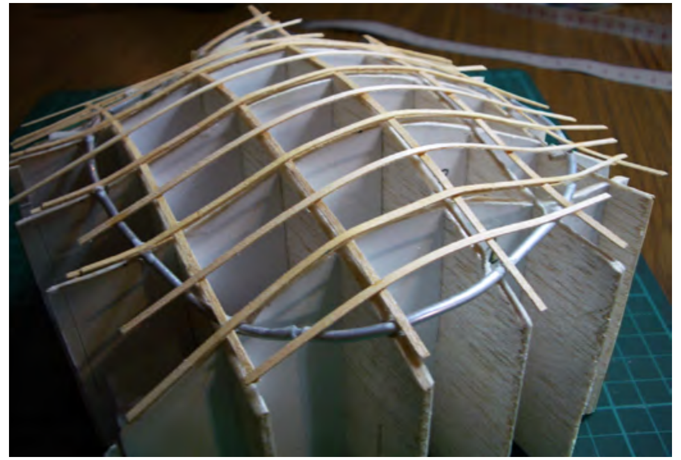


Fig. 254

6.3.5 Development of the gridshell roof

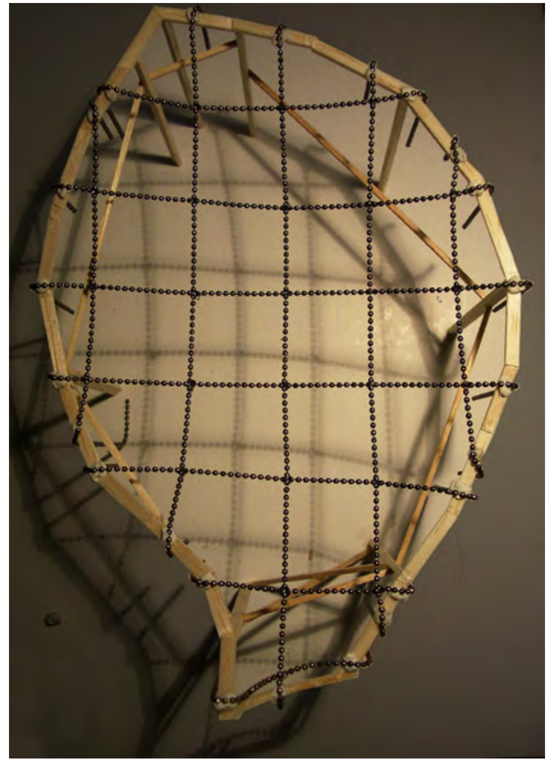


Fig. 252

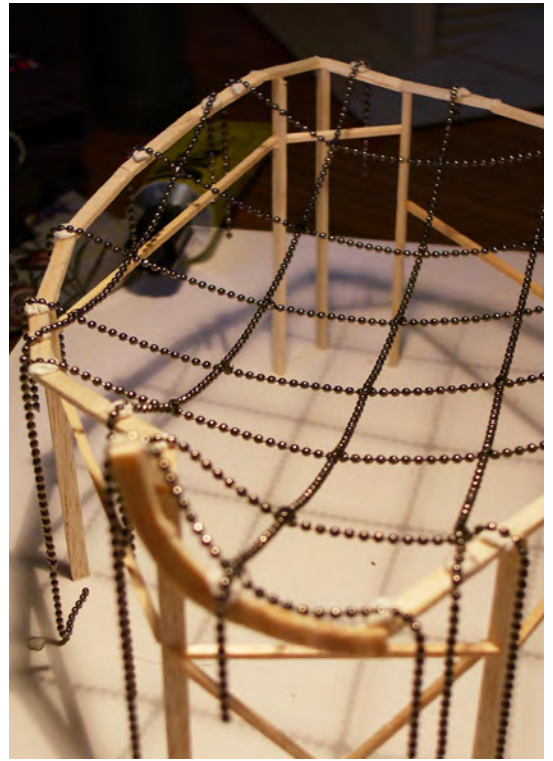


Fig. 255

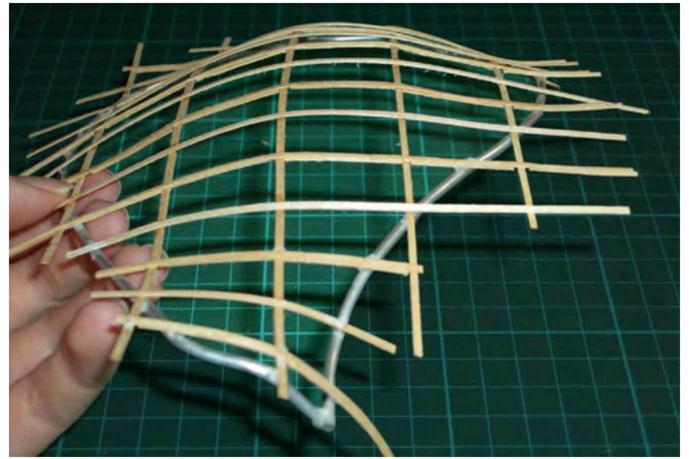


Fig. 256


Fig. 257


Fig. 258

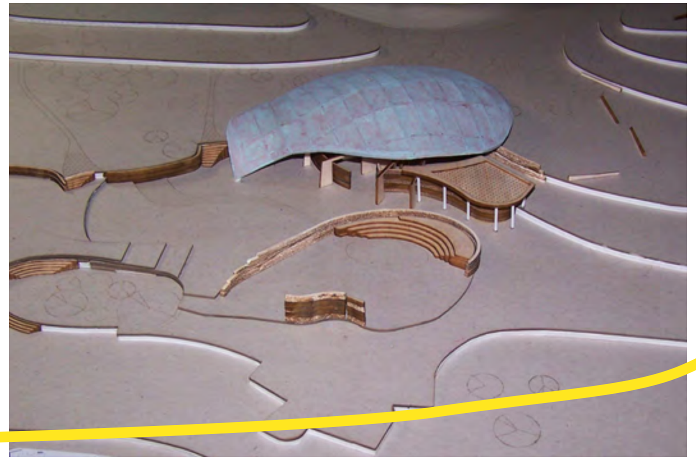


Fig. 259

6.4 COPPER CLADDING

The visual impact of the project on the environment was a concern from the start, thus not only the form, but also the material had to be selected with care. Envisioning an organic form that echoes the surrounding topography, the gridshell structural system was investigated and selected for the central buildings where a focal point is desirable. Elsewhere unobtrusive flat roofs are used that are planted wherever possible.

Copper sheet metal

The most appropriate cover pattern for the copper sheet metal is a diagonal flat seam system. Diamond shaped copper panels are folded along the edges to form flat seams. The diamond shape easily accommodates the irregular curved shape of the roof. Where there is a low roof pitch, the seams are soldered, while the seams of a greater pitch should be treated with sealant. (copper.org)

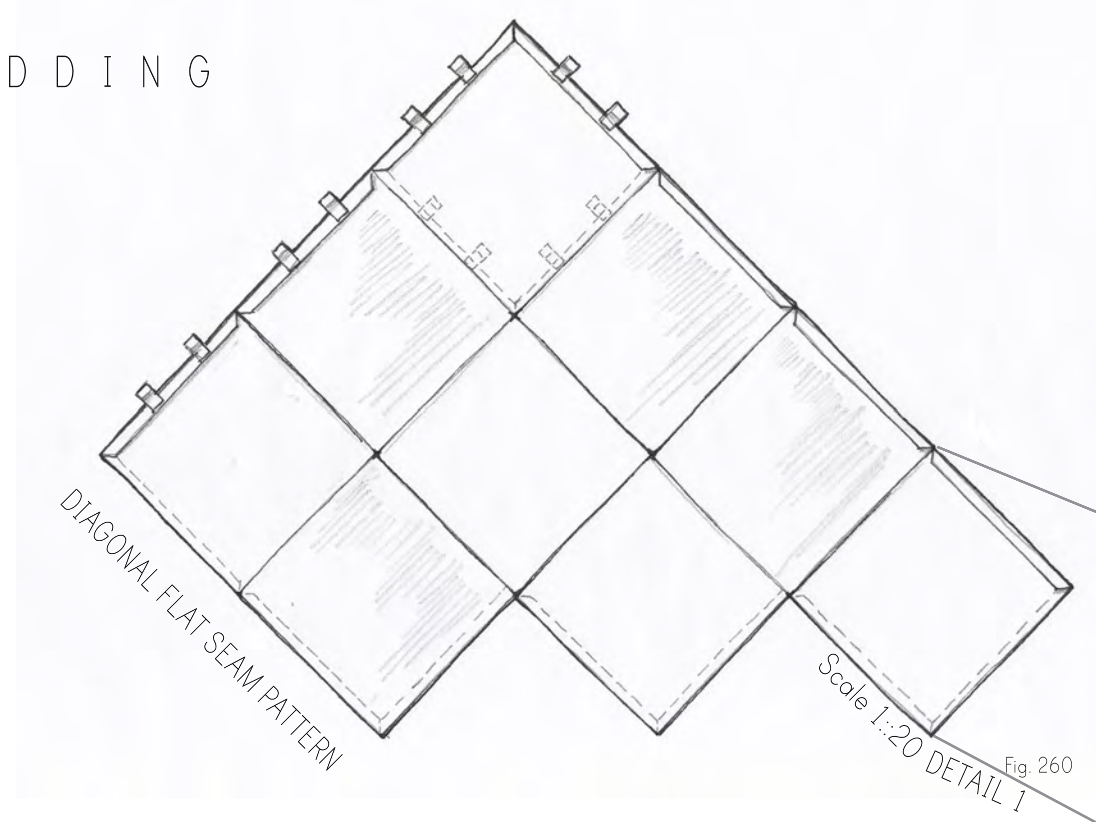


Fig. 260

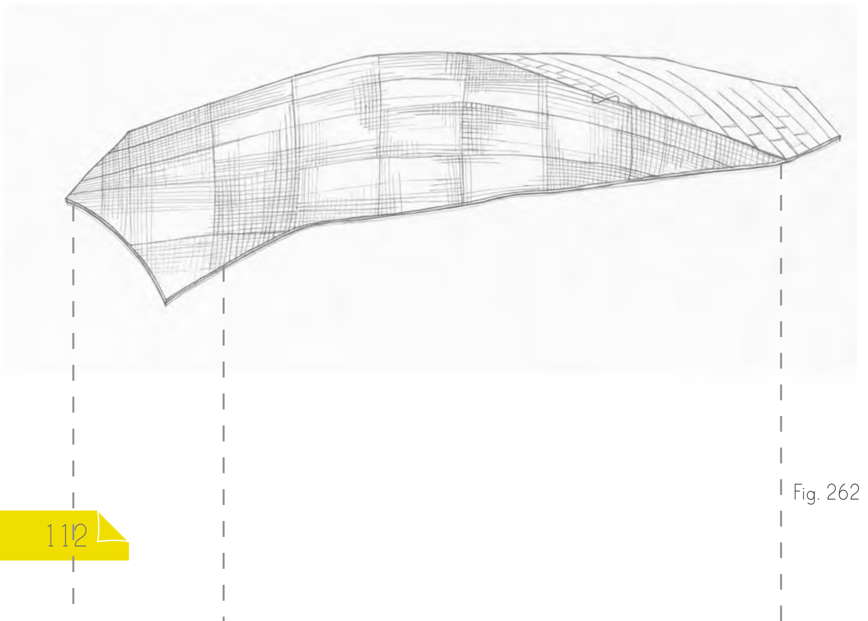


Fig. 262 Exploded view

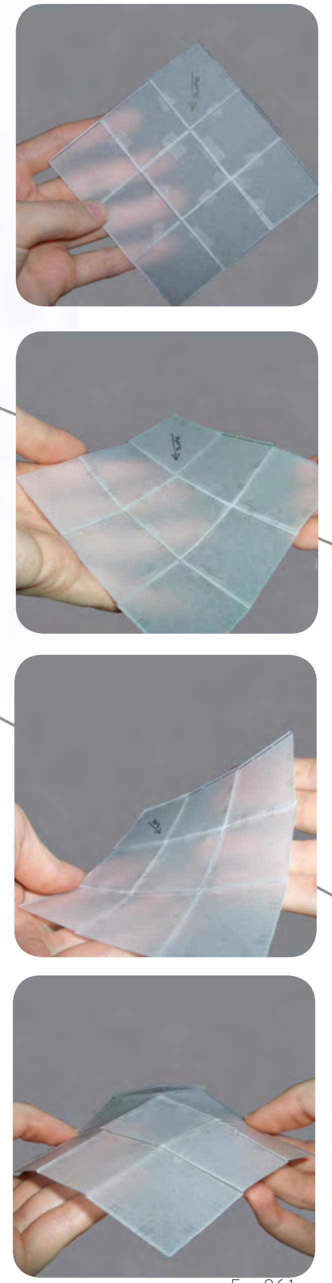


Fig. 261

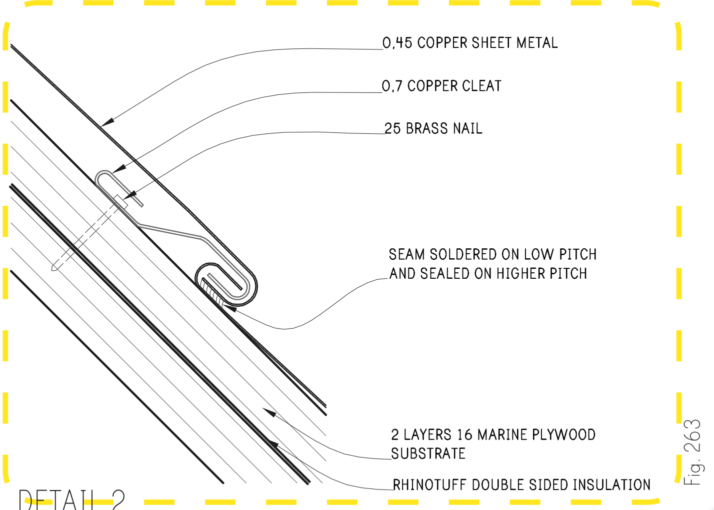
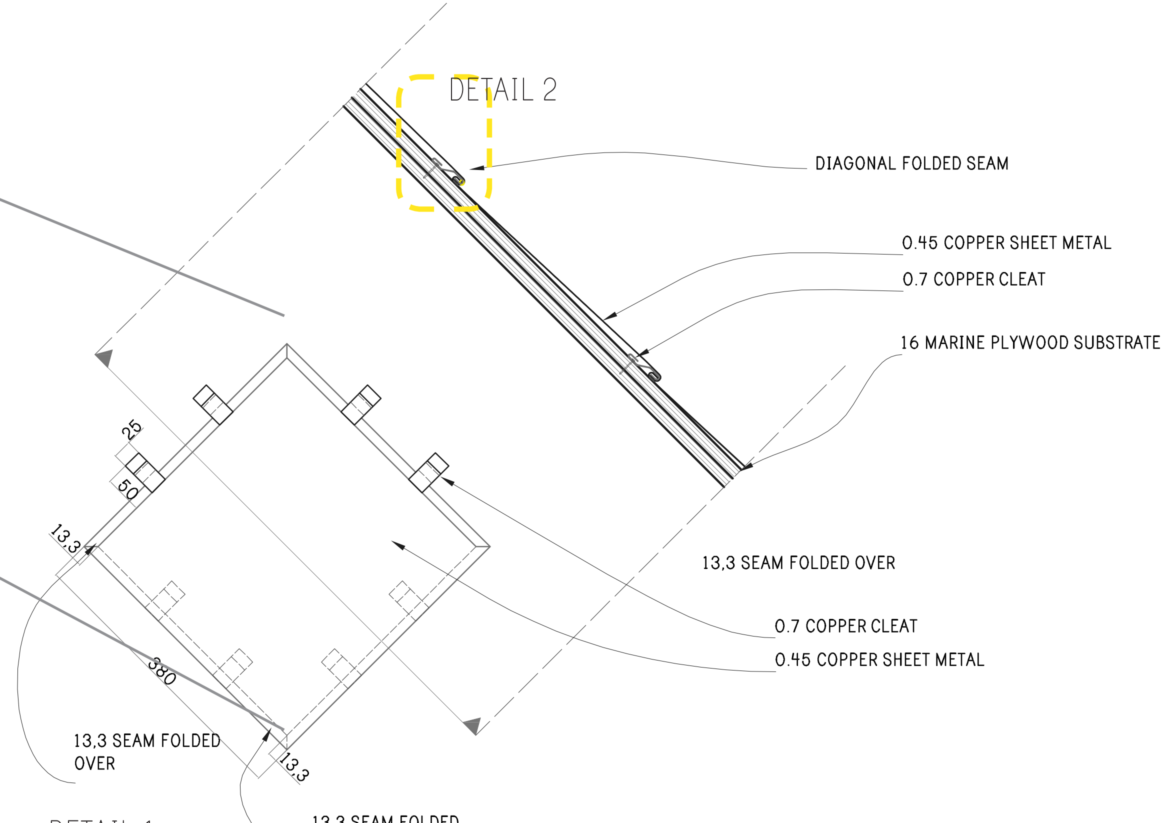


Fig. 263



Scale 1:10
Fig. 264

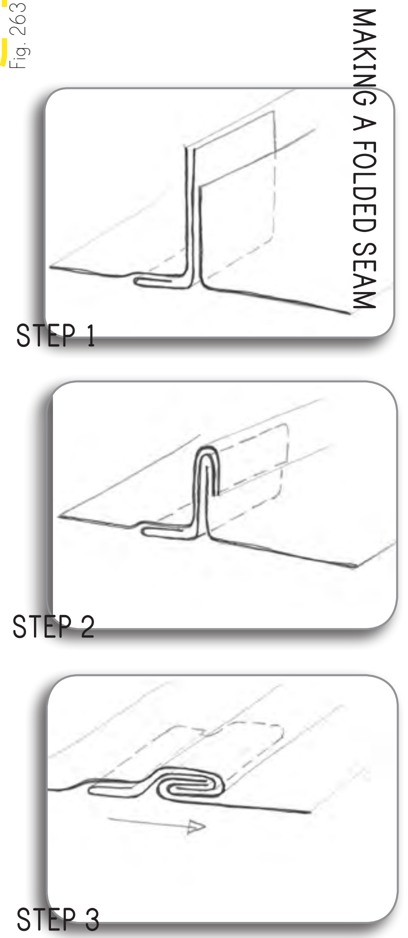


Fig. 265

6.5 GREEN ROOF

Where flat roofs are used, there are various benefits to establishing vegetation.

The visual impact of a green roof when viewed from a higher vantage point, is far less than that of a concrete flat roof. A vegetated roof also makes optimal use of the surface area, as it is possible to cultivate vegetables and herbs on a flat roof.

Further, the thermal advantages of a green roof are possibly the most important. The thermal mass of the earth greatly improves the insulation value of a green roof.

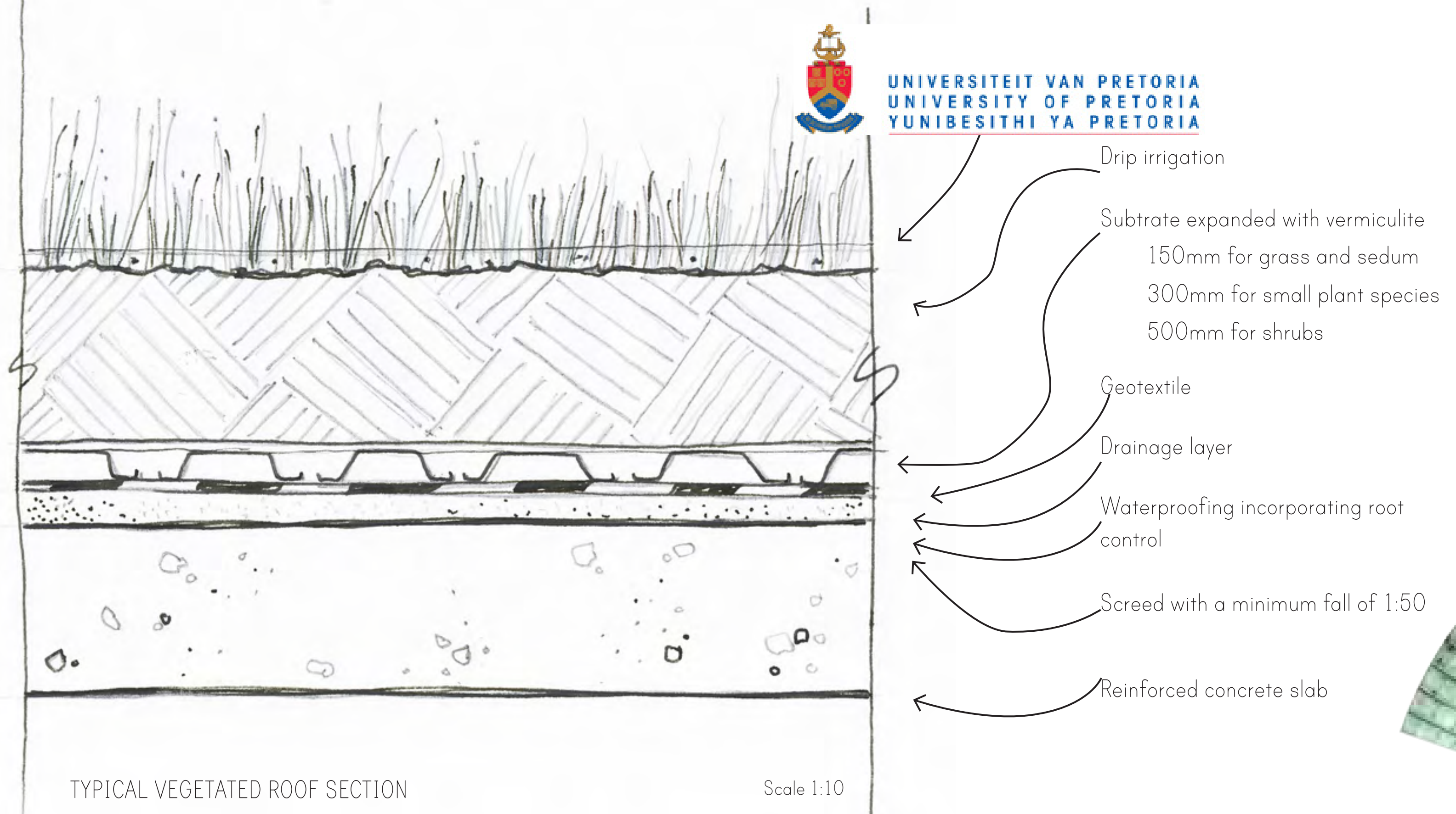
Different types of systems have different requirements such as the depth of the substrate, the types of vegetation that can be planted and the maintenance required. All of these variables determine the structural requirements and cost of establishing and maintaining the green roof.

An extensive green roof type houses vegetation types that only need a shallow substrate, such as grasses. The depth of the substrate would generally be 150mm. The depth of the substrate increases when larger plants such as shrubs and trees are desired. An intensive green roof has a greatly escalated price due to the deep substrate and subsequent structural requirements, as well as higher maintenance and irrigation costs.

The vegetation of an extensive green roof can range from simple turf and sedum to a biodiverse roof that entails the relocation of growth medium from the relevant site to the roof garden. This is done in order to establish vegetation indigenous to the site as well as supporting naturally occurring ecosystems. This type of roof is appropriate where water is scarce, as indigenous plants are suited to the climate of the site. A biodiverse green roof is most successful when substrate depth is varied, which has implications when designing the supporting structure.

A simple system of drip irrigation can be installed, that consists of pipes laid on the substrate.

Fig. 266

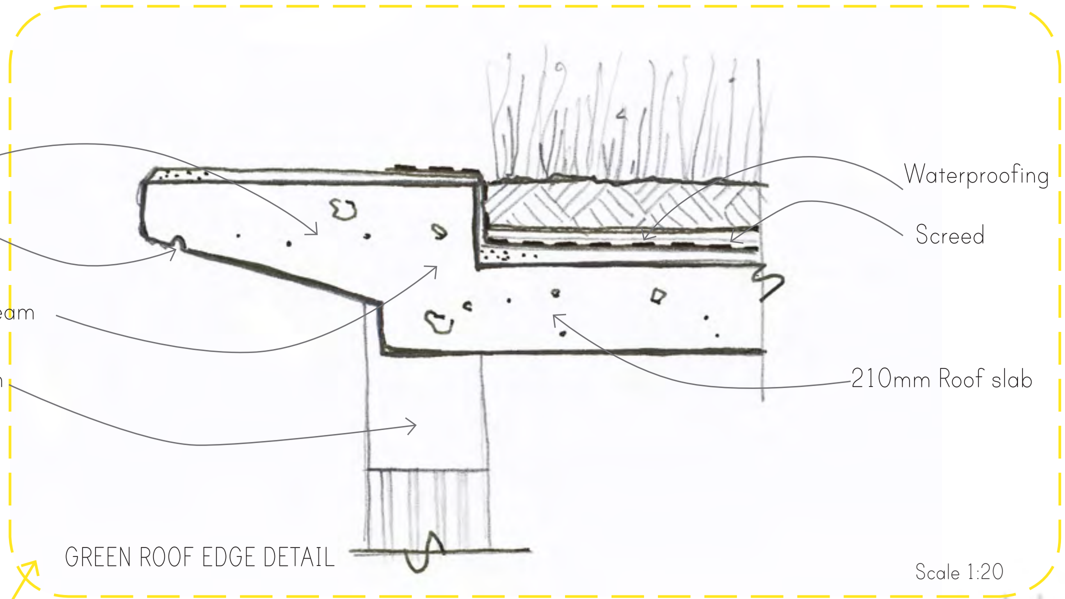


TYPICAL VEGETATED ROOF SECTION Scale 1:10

Fig. 267

Fig. 268 Roof edge NG Universiteitsoord

Fig. 269



GREEN ROOF EDGE DETAIL Scale 1:20

Fig. 272

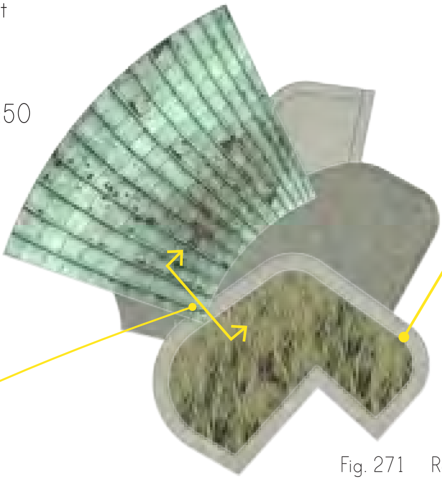


Fig. 271 Restaurant roof plan Scale 1:500

Fig. 274 Roof edge concept

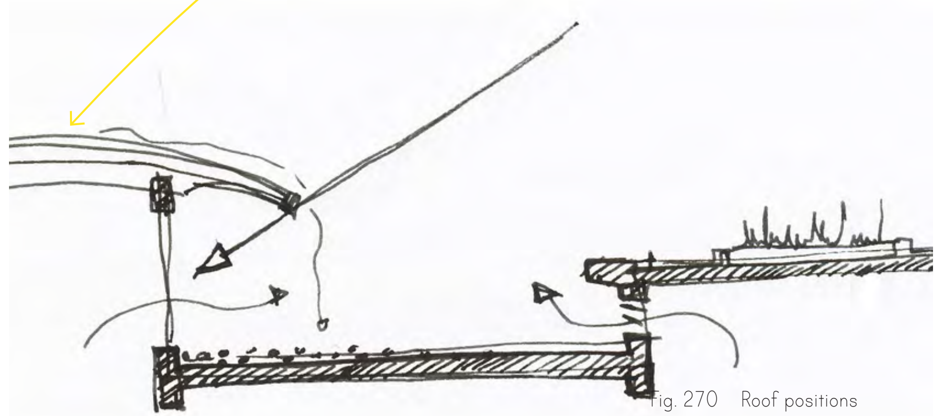


Fig. 270 Roof positions

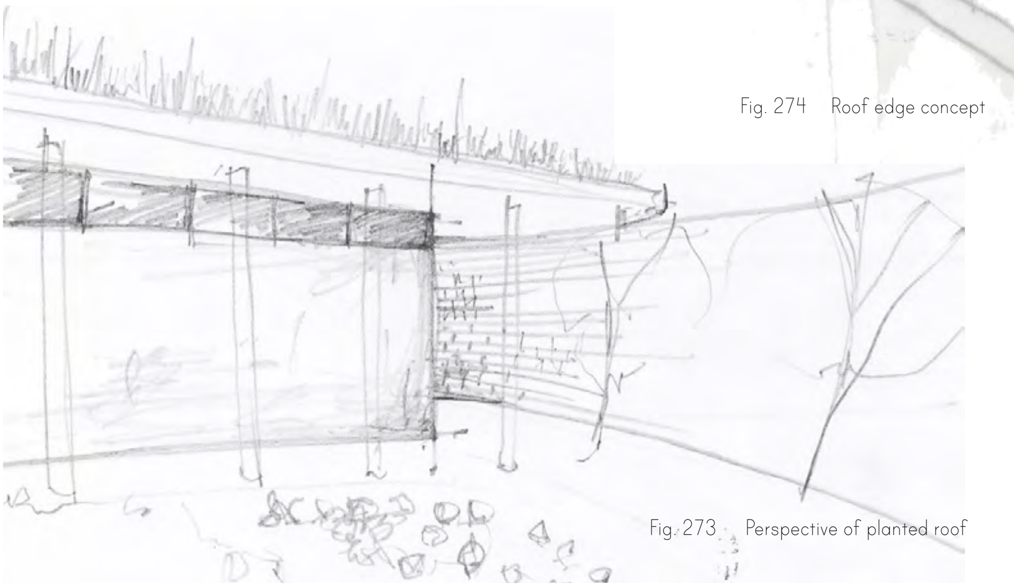


Fig. 273 Perspective of planted roof

6.6 SECTION AA

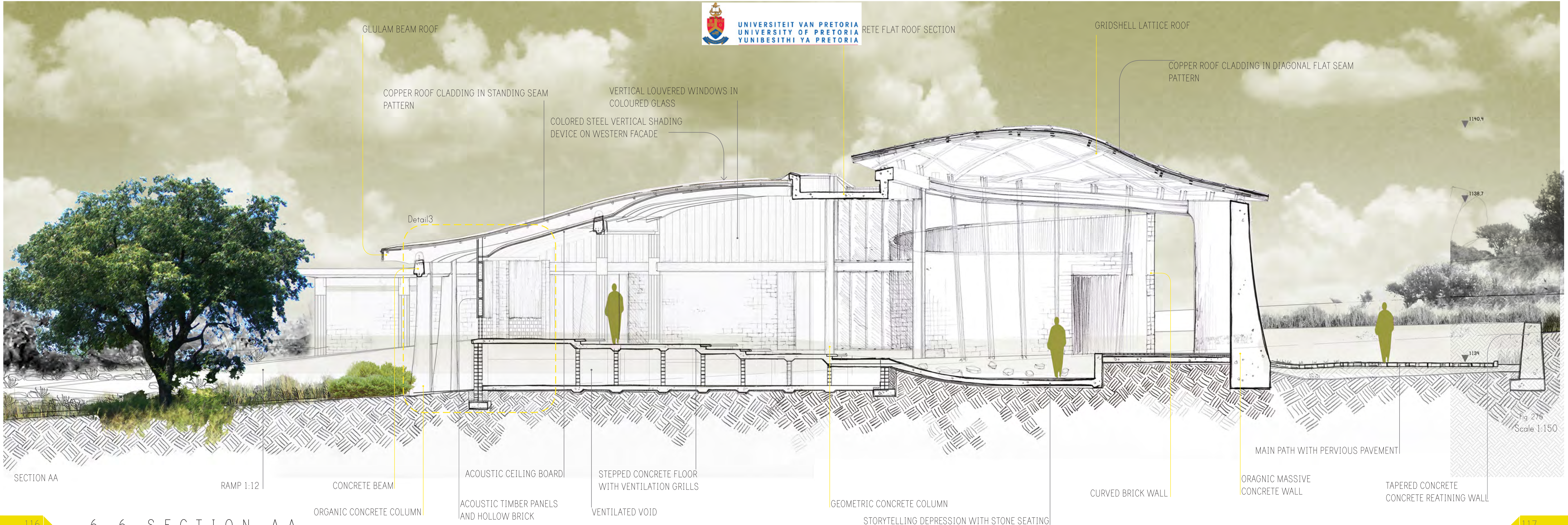


Fig. 275
Scale 1:150

6.7 THERMAL COMFORT

6.7.1 Passive cooling

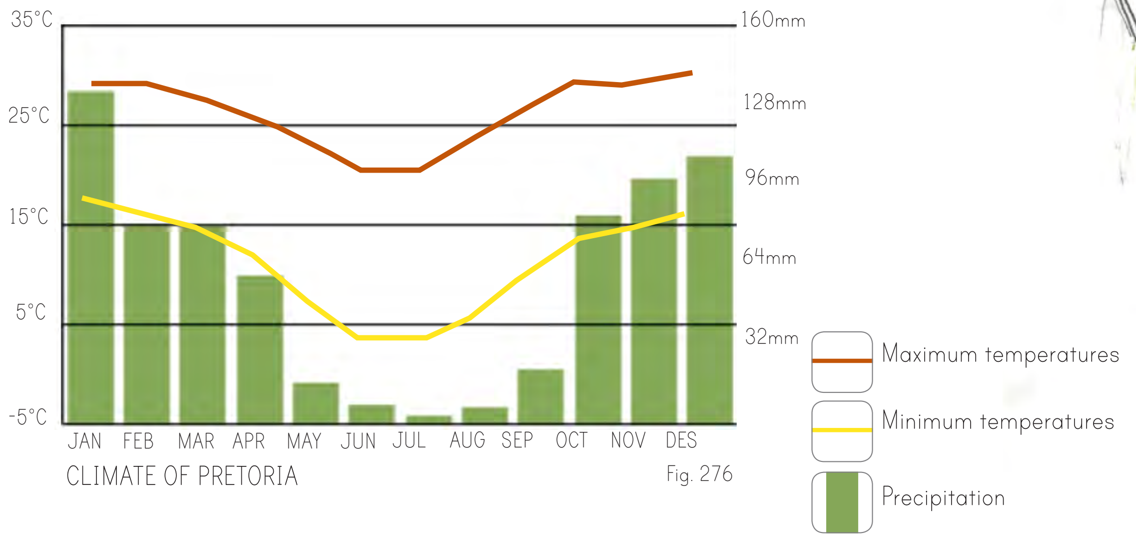
As Tswaing becomes very hot during the summer, an important design consideration is thermal comfort. The need for air conditioning should be kept at a minimum designing in such a way that passive cooling is possible. The most important characteristic of passive cooling is constant air movement. This combats the build-up of heat in a space, while encouraging the cooler air to enter. Most strategies for passive cooling rely on the principle that when hot air rises and is removed, it is replaced by heavier cool air.

This can be seen in the commonly used cooling strategy called stack ventilation. This strategy depends upon high openings that expel rising hot air, creating an air void that is subsequently filled with cool air.

There are other methods that are based on the same principle, such as a trombe wall. The cavity is created with a dark wall on one side and a layer of glazing on the other. Strategic openings in the cavity regulate the flow of hot air, either into or out of the adjacent space thus alternatively heating or cooling the space.

Where the main objective is cooling, a similar but simpler solution is a solar chimney. This structure effectively vents air through the interior space. In this way, heated facades become an asset to the building instead of a problem.

Air flow can also be influenced by the surfaces surrounding the building. Hard surfaces that are heated and reflect heat also causes air to rise, while planted surfaces result in a cool micro-climate. Thus, when these surfaces are strategically applied around the building, air flow through the building can also be encouraged. This process can be enhanced by the size of openings. Smaller openings should be provided where hot air rises, as this becomes a natural vent, sucking air from the interior spaces. Larger openings should be provided near cool areas to ensure the provision of cool air to replace the warm.



CLIMATE OF PRETORIA

Fig. 276

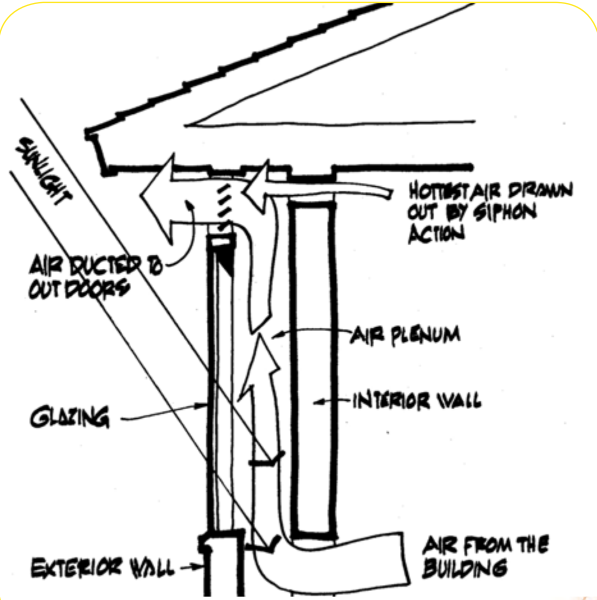


Fig. 277 Solar chimney

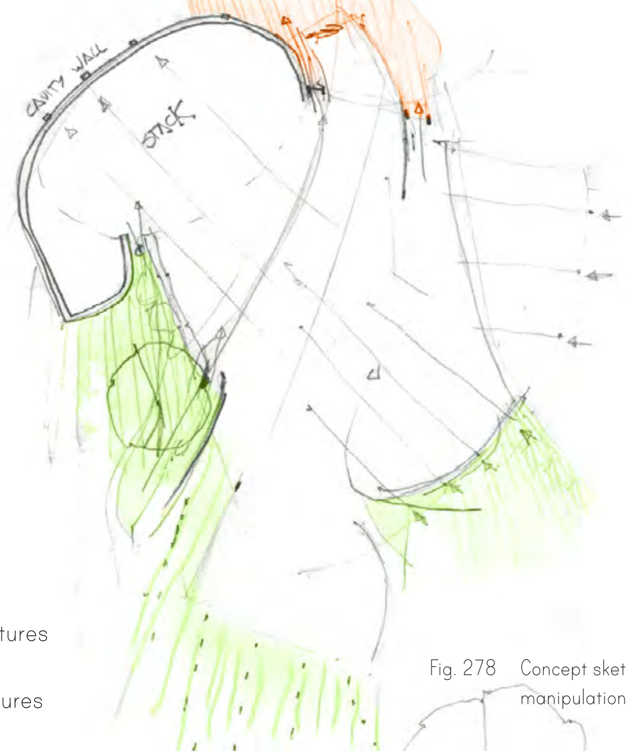
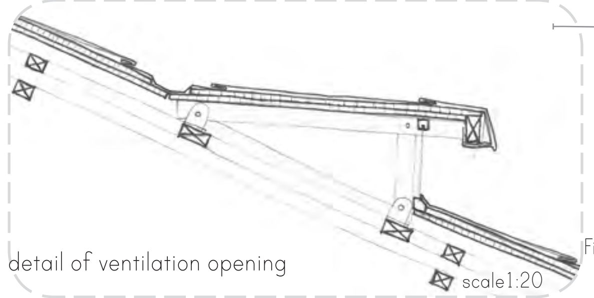


Fig. 278 Concept sketch for the manipulation of the micro-climate



detail of ventilation opening

Fig. 279

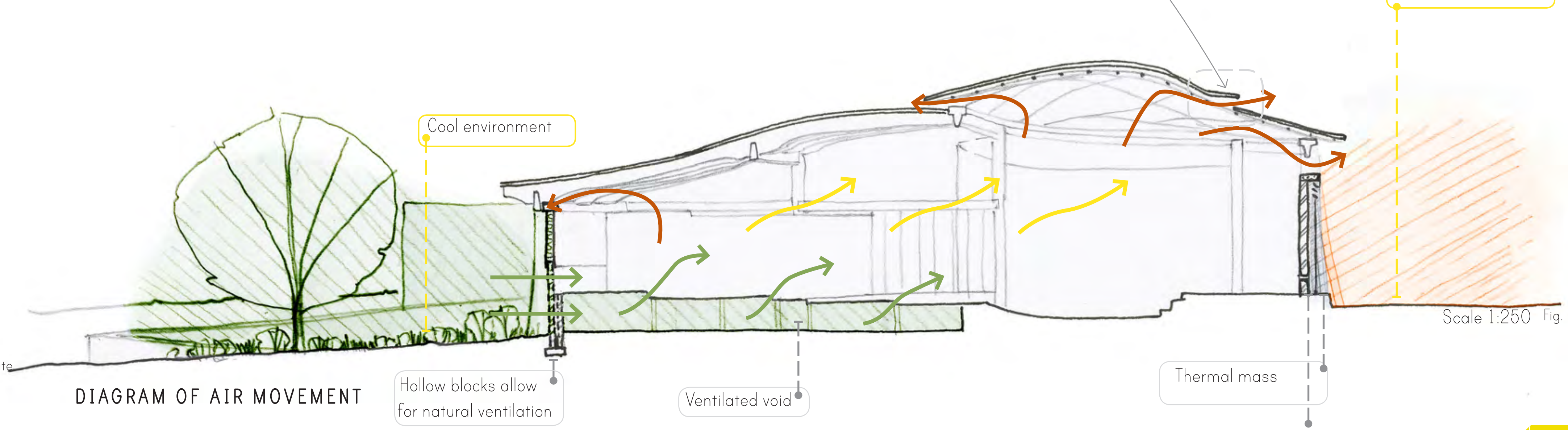


DIAGRAM OF AIR MOVEMENT

Fig. 280

6.7.2 Trombé wall

12:00 21 DECEMBER

Solar altitude: 87°

Solar azimuth: 44°

12:00 21 JUNE

Solar altitude: 41°

Solar azimuth: 19°

15:00 21 DECEMBER

Solar altitude: 50°

Solar azimuth: 280°

The massive concrete wall on the Northern and North-Western facade is articulated with sections of brick wall that act as Trombe walls, or thermo-syphons. The design allows the sections to be orientated towards the sunlight for maximum efficiency.

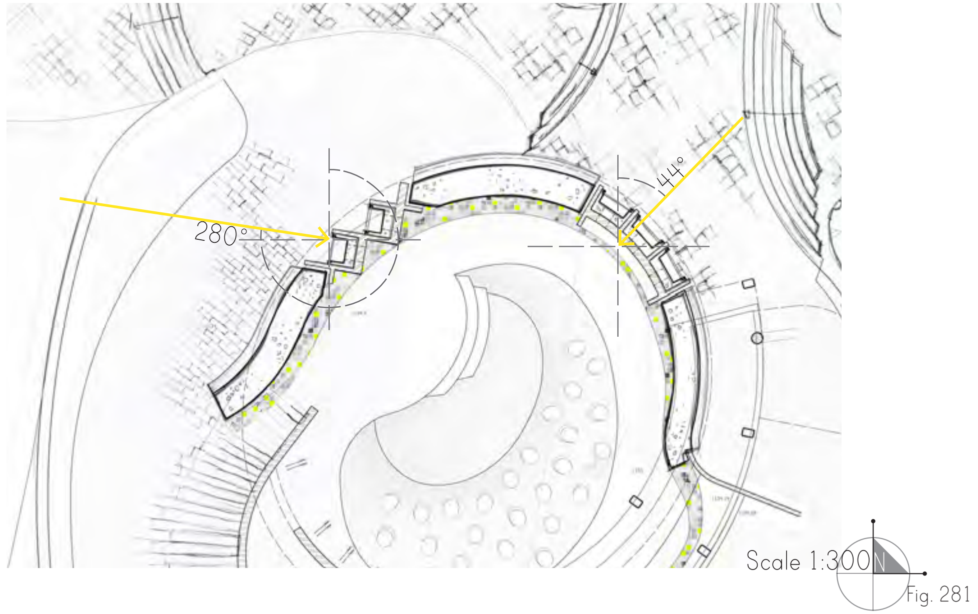


Fig. 281

Trombé wall acting as thermal syphon

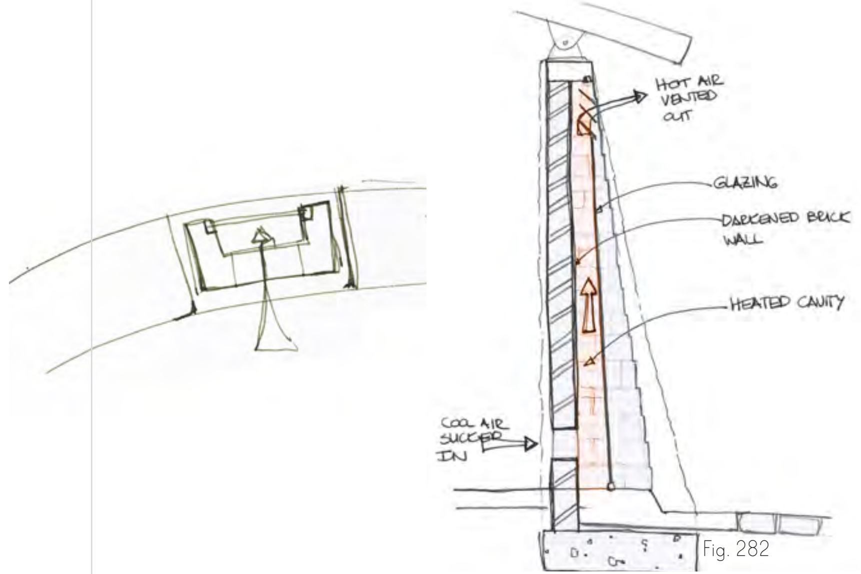


Fig. 282

DETAIL 4 (rough)

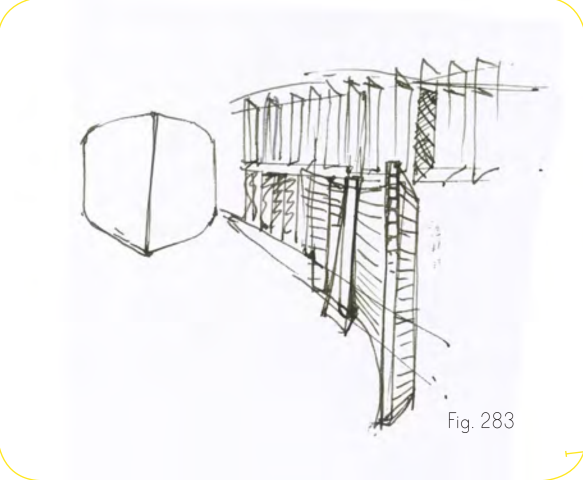


Fig. 283

Fig. 284

Scale 1:100

6.7.3 External shading devices

Sizing calculations of the external shading devices establish the overhang, depth and spacing of the fins for effective shading according to the position of the sun.

Northern facade

Depth of overhang for 2000mm window shading

$$h = \frac{D \times \tan(\text{solar altitude})}{\cos(\text{solar azimuth} - \text{window azimuth}}$$

$$2000 = \frac{D \times \tan(87^\circ)}{\cos(33^\circ)}$$

$$2000 = \frac{D \times 19{,}08}{0.84}$$

$$D = 88{,}05\text{mm}$$

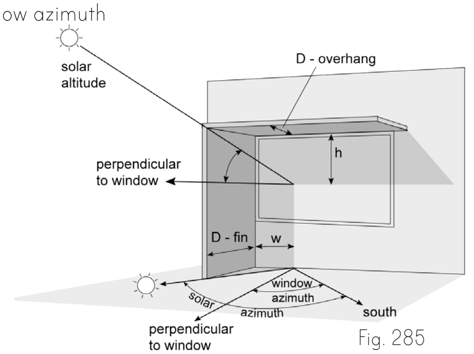


Fig. 285

South-Western facade

Spacing of fins assuming depth of 550mm

$$w = D \times \tan(\text{solar azimuth} - \text{window azimuth})$$

$$w = 550 \times \tan(280^\circ - 258^\circ)$$

$$= 550 \tan 22^\circ$$

$$= 222\text{mm}$$

Overhang

$$h = \frac{D \times \tan(\text{solar altitude})}{\cos(\text{solar azimuth} - \text{window azimuth})}$$

$$h = \frac{550 \times \tan 50^\circ}{\cos(22^\circ)}$$

$$h = \frac{655{,}46}{0{,}93}$$

$$h = 704{,}8\text{mm}$$

D= 550mm

w= 225mm

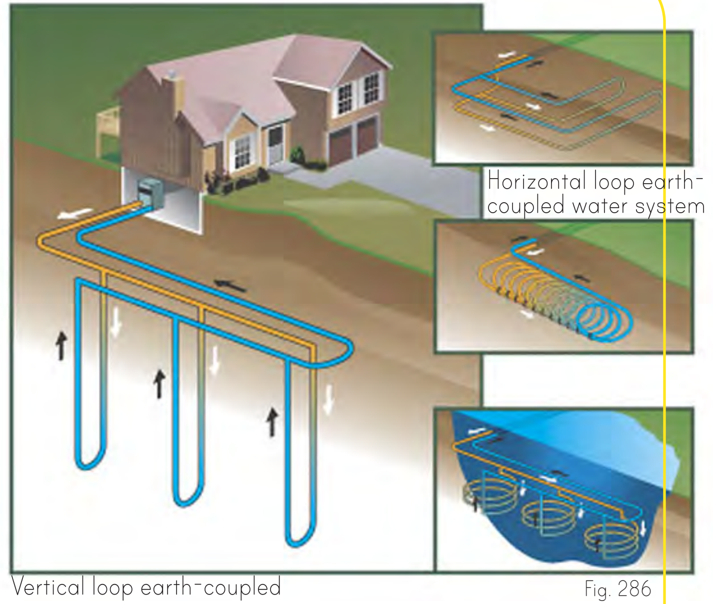
h= 710mm

6.7.3 Earth-Coupled Cooling

In addition to passive climate control, air conditioning systems may be necessary, especially during the warmest times of the day. As HVAC systems are not very energy efficient, natural cooling such as an earth-coupled air cooling system can be considered.

The system relies on the fact that the temperature of the earth is much more constant than the fluctuating air temperature.

Different systems of earth-coupling exist, the main categories being those that operate using water and those that operate using air. Ground-coupling water systems can be installed in a horizontal loop configuration and vertical loop configuration. However, these methods require the disturbance of large areas of the landscape and additional equipment such as a water furnace that greatly escalates the cost of the system. As this is not desirable within the context of this project, a ground-coupled air system will be proposed.


Horizontal loop earth-coupled water system

Vertical loop earth-coupled water system

Fig. 286

The system consists of length of pipe laid underground with a n intake a distance from the building. The air is pumped to the building with a normal air-handling unit . The air is cooled by the lowered temperature under the ground and then distributed to the building. A depth of 2- 5m is recommended for a stable temperature. Piping laid underground is connected to an air intake a distance from the building at one end and connected to the air handling system intake at the other end. This can be used to pre-heat or pre-cool the building and significantly reduce the mechanical cooling requirements. The simple system can achieve a cooling effect of up to 45 W/m^2 at an outside air temperature of 32°C, a reduction of 11°C at an average temperature of 28°C (Pennycook 2008:36) The system can effectively pre-cool the building, requires very little maintenance and no equipment in addition to the traditional air conditioning system .(Pennycook 2008:36)

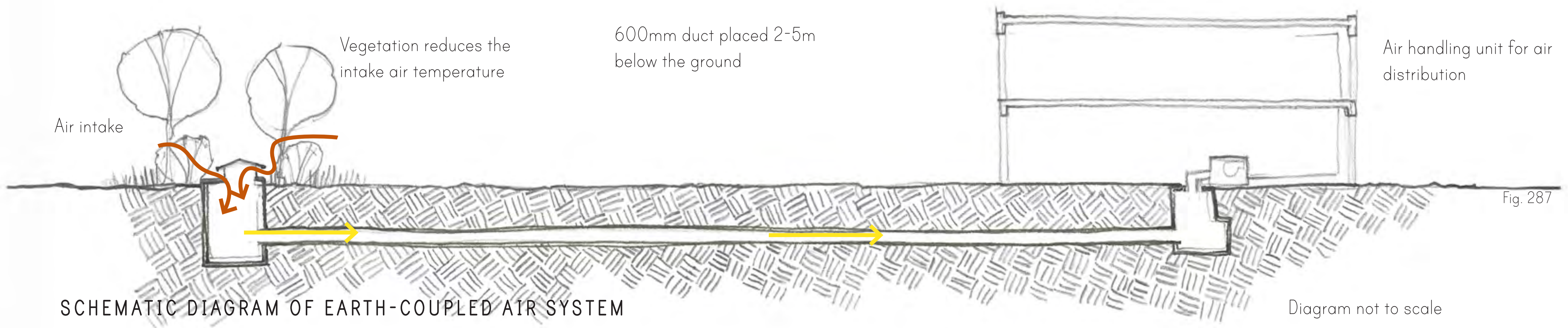


Fig. 287

SCHEMATIC DIAGRAM OF EARTH-COUPLED AIR SYSTEM

Diagram not to scale

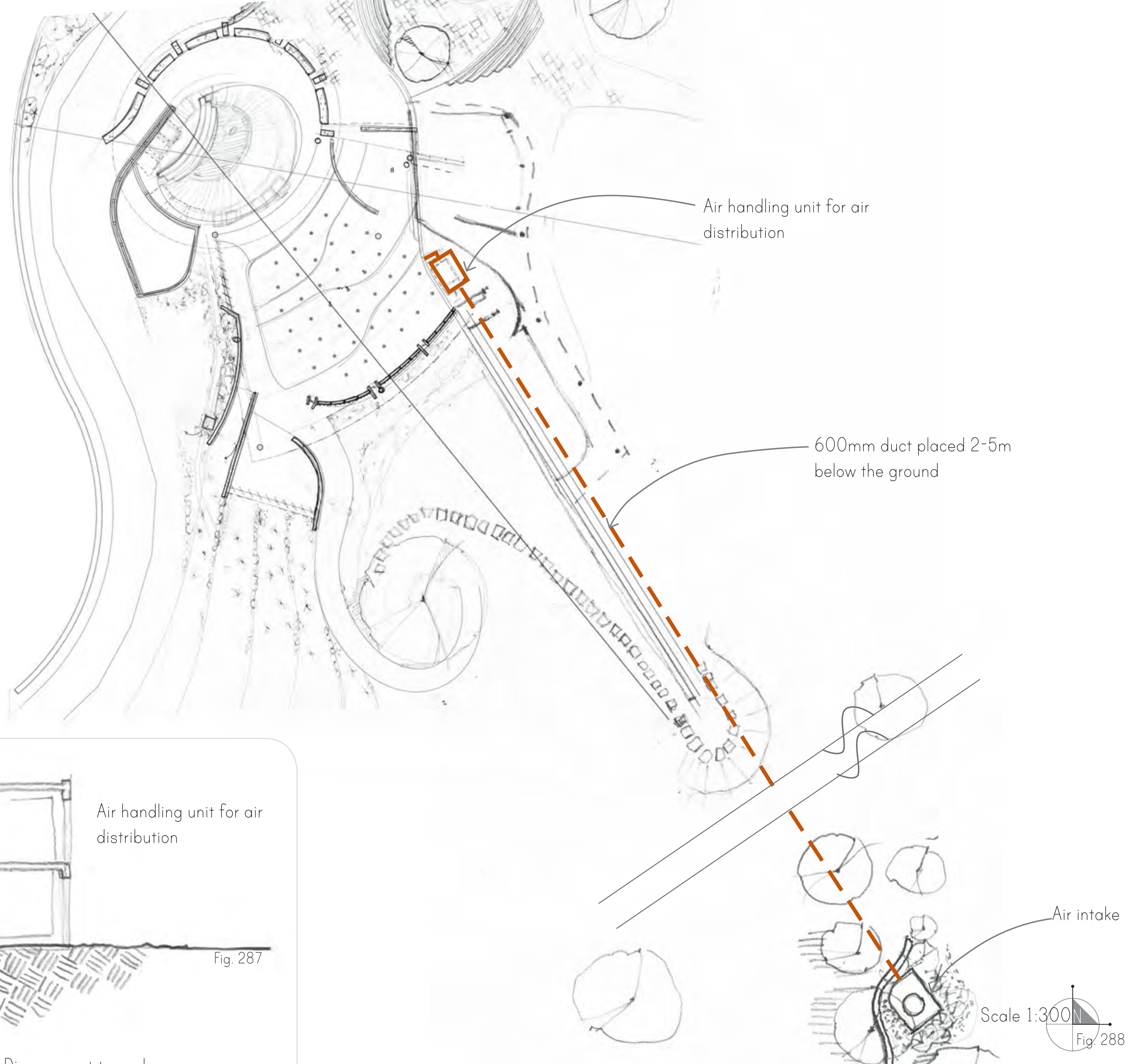
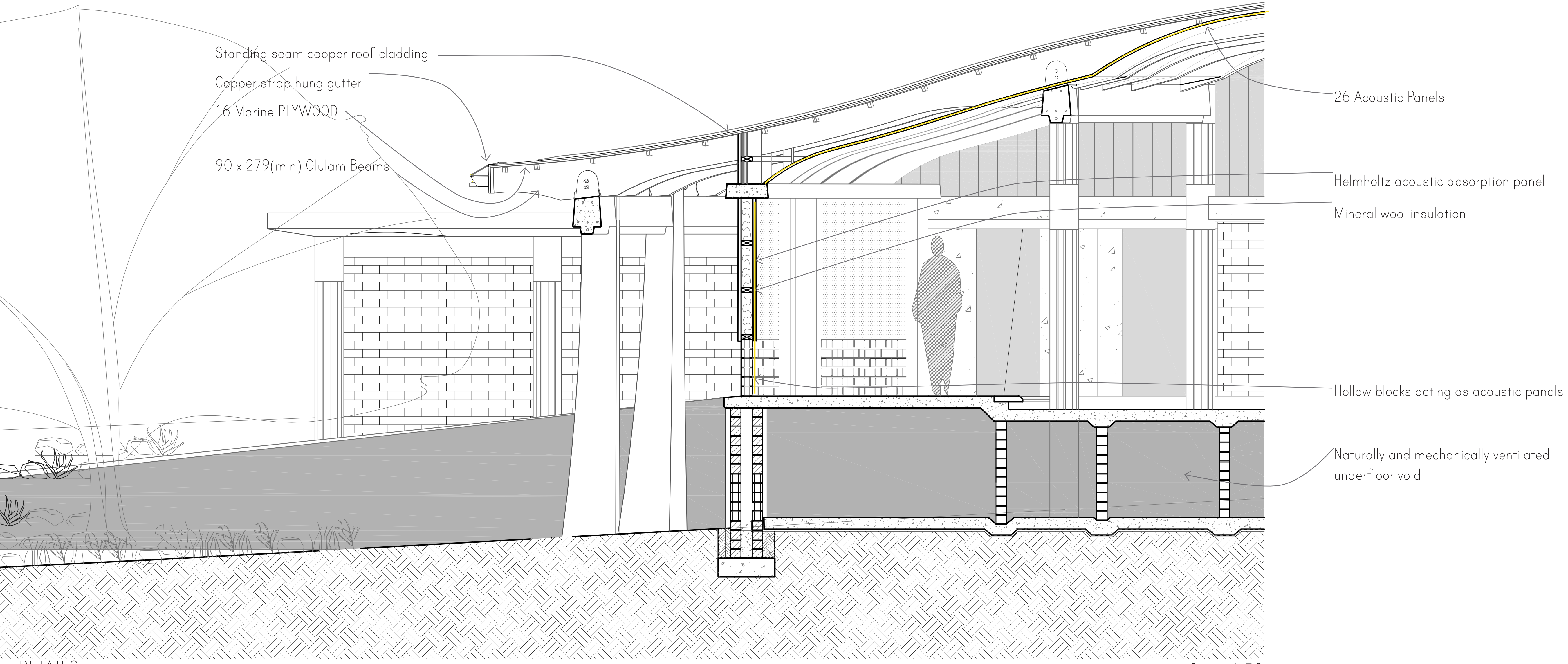


Fig 288

SCHEMATIC DIAGRAM OF EARTH-COUPLED AIR SYSTEM



DETAIL3

Scale 1:50

Fig. 289

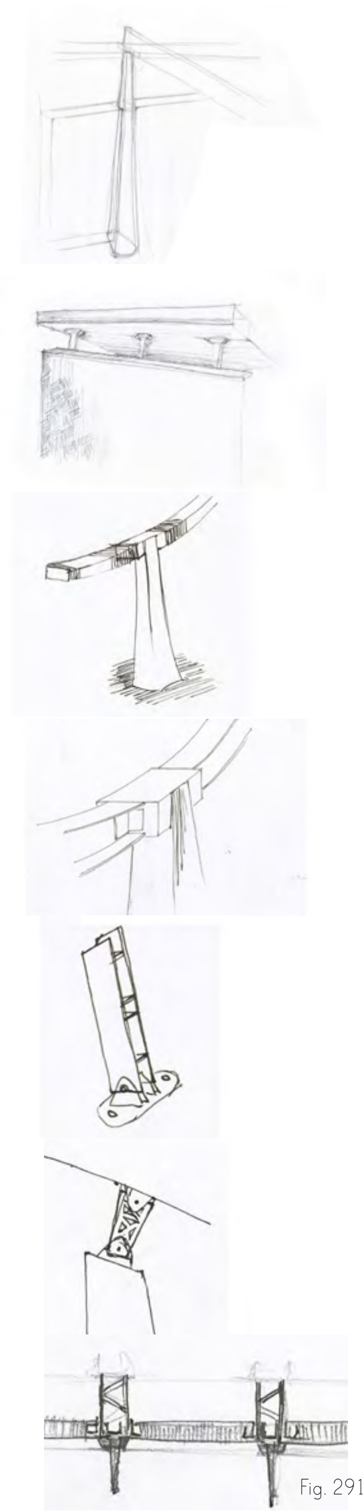


Fig. 291 Connection concepts

6.8 ACOUSTIC PERFORMANCE

The programme of storytelling hall involves a small theatre, a children's nook, and workshop space in the semi-basement area. The theatre space contains fixed seating, casual seating and a depression in the floor with low seating. The programme will mostly entail dramatic performance, although small-scale musical performance may be possible. Thus the acoustic performance of the building is an important design guideline.

The main considerations are:

The reduction of background noise

"When a theatre is truly quiet, an actor can use his entire dynamic rage, from a shout to a whisper, and still. be clearly understood." (Brooks:p.2) The art of storytelling has been explained to be a dynamic and interactive experience (chapter 5), and thus the importance of a quiet environment is reinforced by the specific programme of the building.

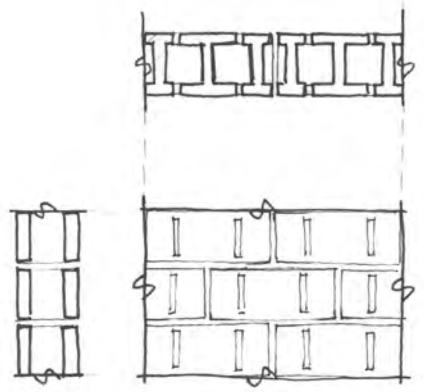


Fig. 290 Plan and section of hollow blocks

Historically, the main concern of the acoustic engineer and architect had been reverberation time.(Edwards 1984:133) Reverberation time is determined by the cubic volume of the room and the absorbing power of the room surfaces and contents. (Edwards 1984:133) However, little was known about the effect of the building form and the reason for alterations in the acoustic success of different building forms.

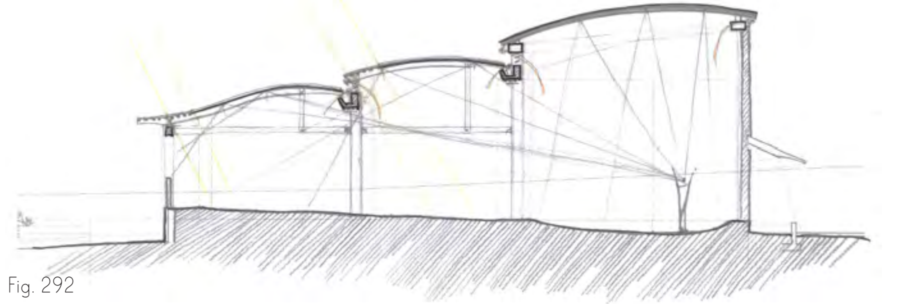


Fig. 292

6.9 STORMWATER TREATMENT

In a climate such as Tswaing where parts of the year are dry and precipitation consists mostly of thunderstorms, attention should be given to the ability of the landscape to retain water. During a thunderstorm, surface water does not infiltrate fast enough and a lot of runoff goes to waste. This also causes erosion, a real threat to the landscape at Tswaing. Therefore, measures should be taken to increase the infiltration rate and slow the flow of water down.

6.9.1 Grassed swales

A grassed swale is a landscape intervention that directs and slows stormwater runoff, as well as maximizing infiltration. (Maryland Department of the Environment 2000)

The vegetated parabolic channel system is constructed by replacing native soil with highly permeable soil and installing an underdrain system embedded in gravel. (Metropolitan council 2002) Further, the channel is planted with resilient vegetation that slows the flow of stormwater, increasing attenuation. Vegetation should be selected for its deep root system, high stem density and resistance to flooding. (Duluth streams 2009)

Check dams can also be included in the design as attenuation structures where the slope exceeds 4 percent. (Maryland Department of the Environment 2000)

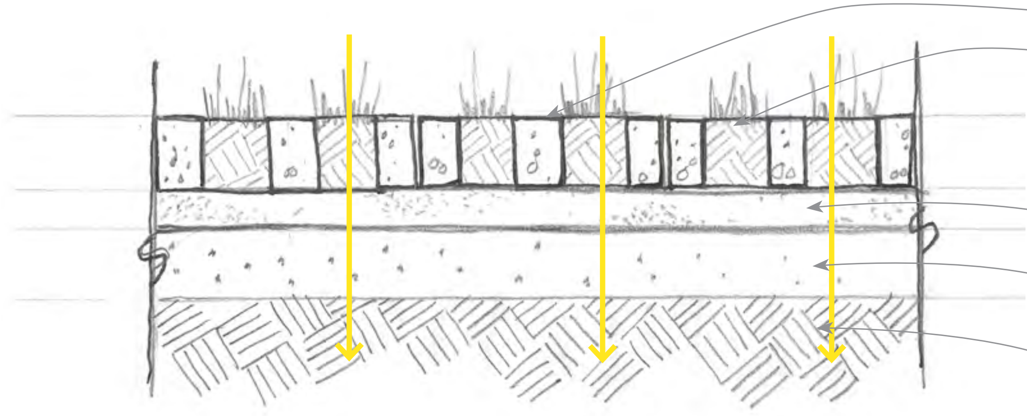


Fig. 293

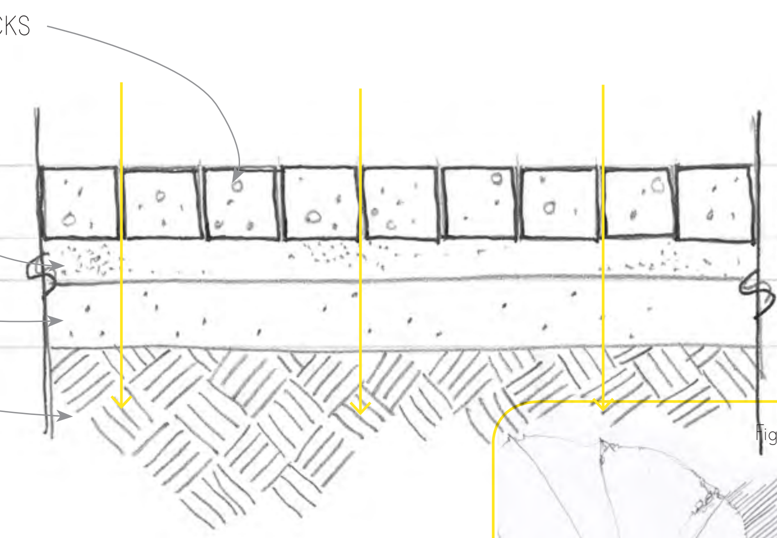
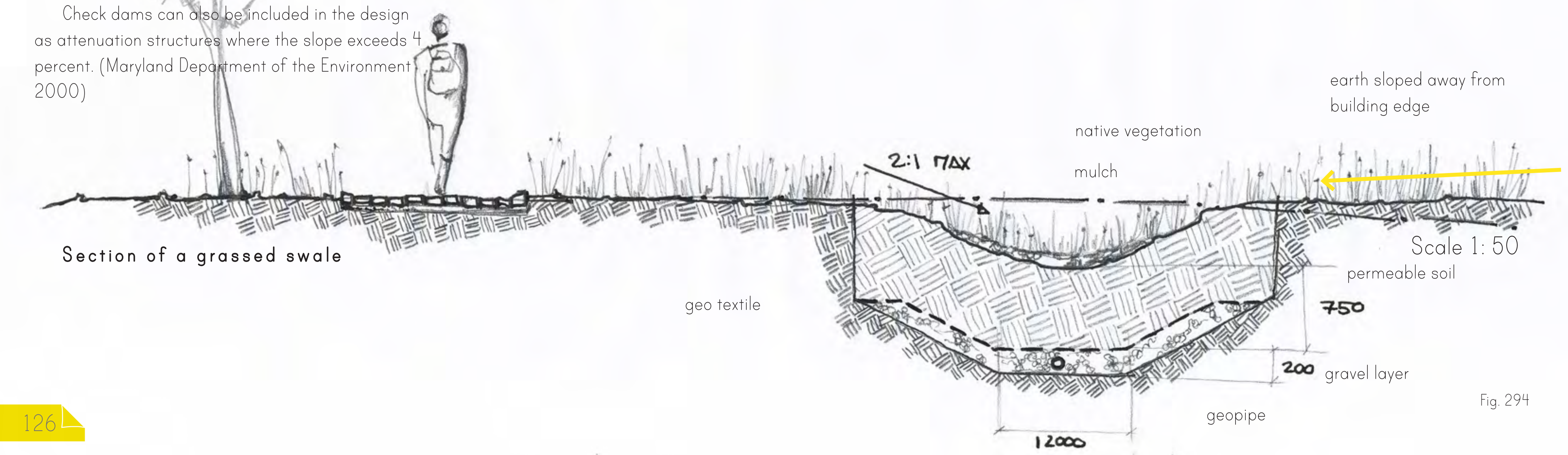


Fig. 295



Section of a grassed swale

Fig. 294

6.9.2 Pervious Pavement

As the site plays host to many paths and potentially hard outside surfaces, methods of maximising stormwater infiltration are employed. Hard surfaces increase stormwater runoff that can cause erosion and carries harmful pollutants into the water sources on the site. Retaining stormwater in the site allows improves conditions for landscape intervention as well as food gardens in service of the project. Existing paths are at risk of being damaged by erosion, especially since greater foot traffic is to be expected from visitors to the site. Treating the paths with pervious pavement not only stabilizes the earth, but does not cause the runoff problems that other hard surfaces do.

Different types of pervious pavement are used. The textured appearance and the use of gravel and grass in certain pavers may indicate transitional zones from the paths to the buildings and also echoes the landscape in the built environment. These can effectively be combined with normal (pervious) paving and planted areas.

Fig. 296 Perspective of path along wall

Fig. 297

Fig. 298

6.9.3 Rainwater Retention

Precedent

Portland Water Pollution Control Laboratory

The sections are typical details of the stormwater solutions employed at the BES Water Pollution Control Laboratory in Portland.

In certain instances, where the design allows rainwater to cascade freely off a roof, or where water flows from scuppers at a height, the water may cause erosion around the buildings. To avoid a situation where hard surfaces are used to prevent this, large stones may dissipate the energy of the falling water and the spread the water into the surrounding landscape. (Liptan et al 2002:27) A gentle slope away from the building can serve as a vegetative filter(Liptan et al 2002: 16) Check dams serve as water spreaders that reduce the speed of flowing water. These are constructed from non-toxic material such as stone, brick or old concrete and a minimum length of 3000mm. The slope should not exceed 10%.(Liptan et al 2002: 25)

Planters with a pervious bottom are also beneficial to water infiltration. The reservoir of storage required can be calculated as follows: impervious area in square meter x. 0.45 =reservoir in cubic meter. The minimum infiltration rate is 50mm/h. (Liptan et al 2002: 16)

The above interventions will aid the designer in creating cool planted area around certain parts of the buildings. Microclimate can be manipulated to induce air flow from cool environments to warm.

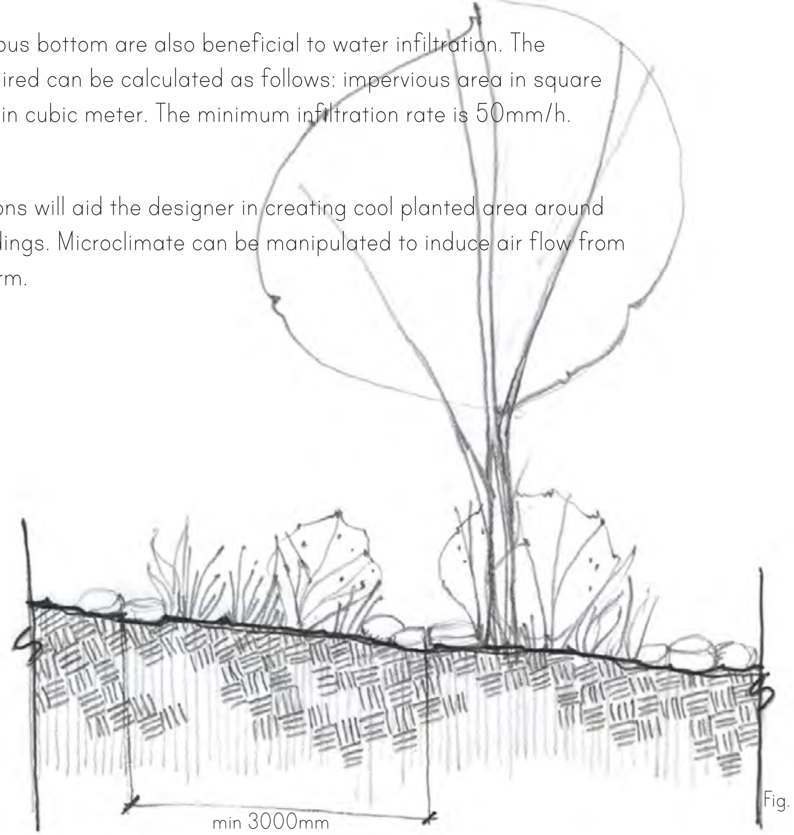
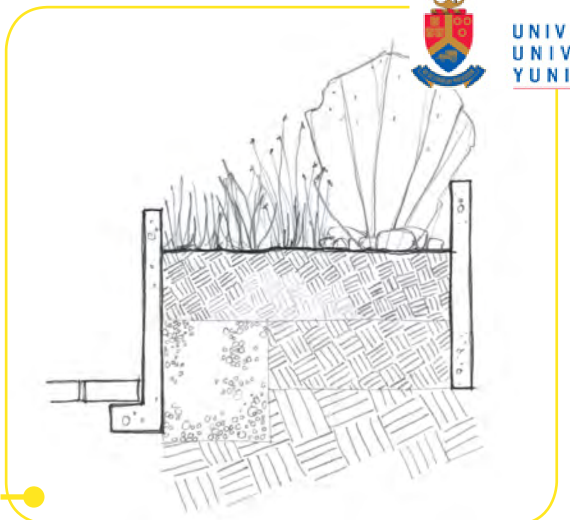


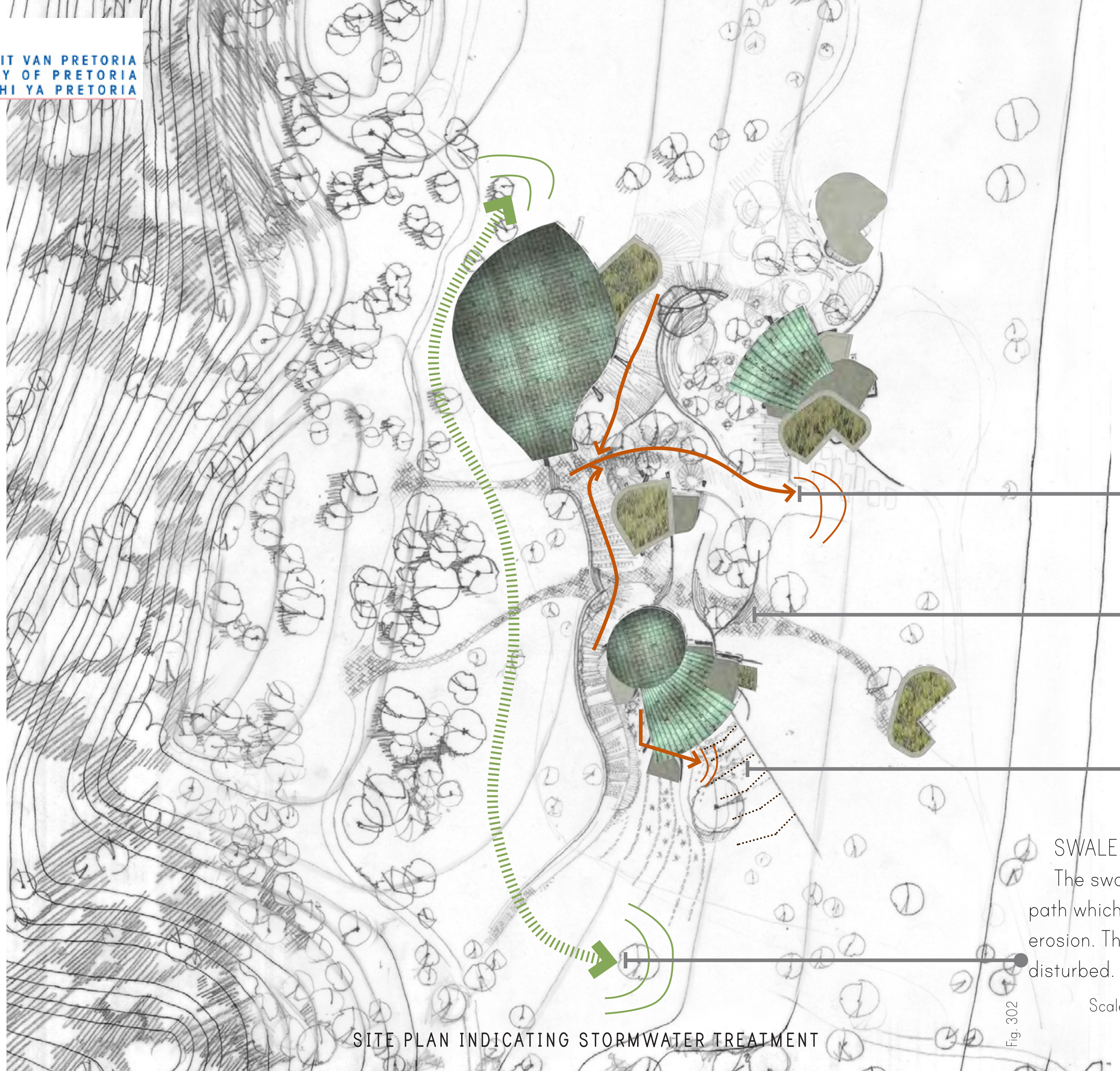
Fig. 299

Section of a vegetation filter *(not to scale)*



Section of an pervious bottom planter *(not to scale)*
Fig. 300

Fig. 301 Portland Water Pollution Control Laboratory



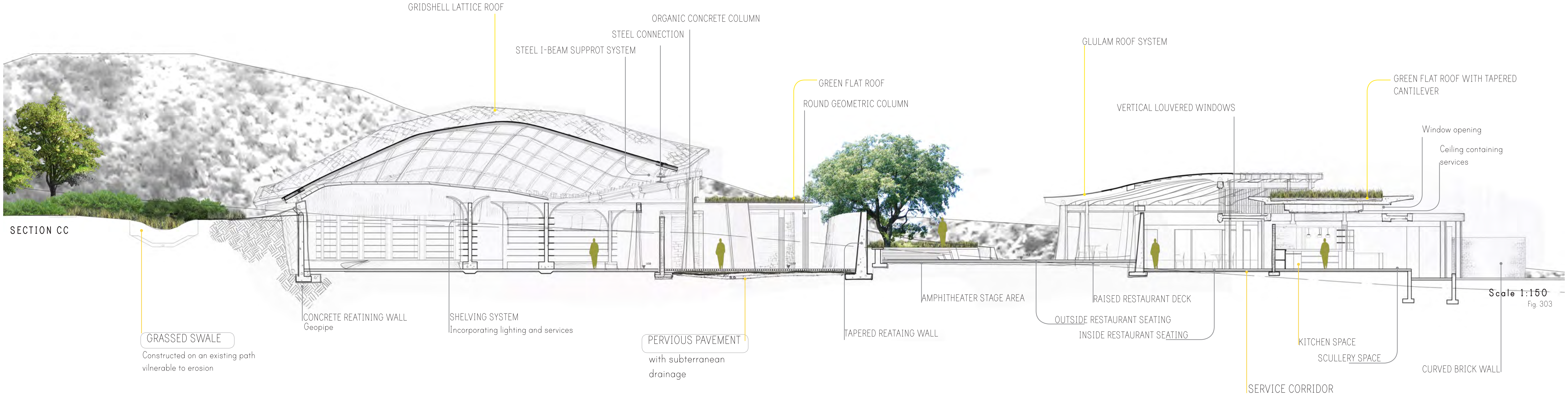
SWALE

The swale indicated runs along an existing path which, if left untreated, may accelerate erosion. Thus, the earth is not unnecessarily disturbed.

Scale 1:750

Fig. 302

SITE PLAN INDICATING STORMWATER TREATMENT



Scale 1:150
Fig. 303

6.10 SELF-COMPOSTING TOILETS

Connecting the remote site of the project to a sewer line would be costly and harmful to the sensitive environment. Conventional toilet systems also require large amounts of water that is effectively wasted and contaminated. For these reasons a self-composting toilet system is suggested.

Self-composting toilets are self-contained aerobic break-down system that does not require water. Aerobic bacteria are organisms that thrive in aerobic conditions and break down excrement into a humus. The humus reduces the original volume of waste to 10 to 30 percent and can then be buried according to regulation.(United States Environmental Protection Agency 1999: 1)

Managing the self-composting system is of the utmost importance, but simple. No specialist labour is required to maintain the system. Maintenance entails, the regular addition of bulking agents such as ash or sawdust and the removal of the end-product.(United States Environmental Protection Agency 1999: 6)

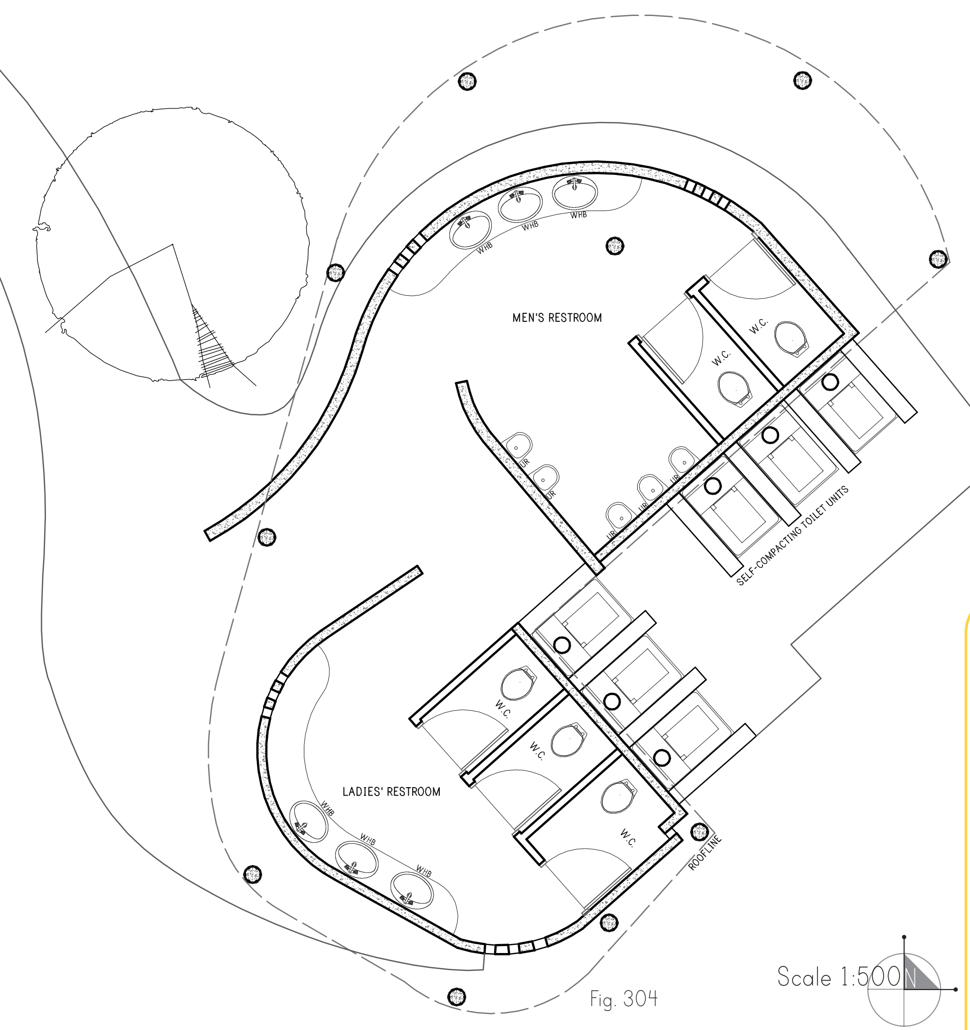
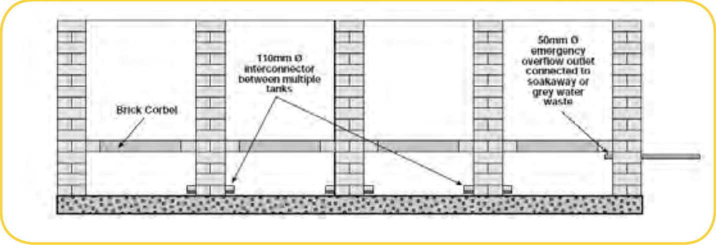


Fig. 304



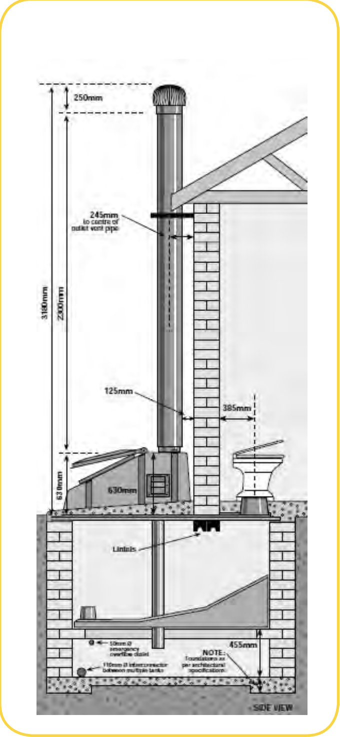


Fig. 305

6.11 GREYWATER SYSTEM

Having addressed black sewage disposal, one should consider the recycling of grey water. Bathroom and kitchen sinks, dishwashing machines and water points, all present on the site use enormous amounts of clean water. Grey water is defined as washwater. (greywater.com) Although grey water will become similar to blackwater if left untreated for a few days, it is a great source of minerals when used for irrigation quickly.

A grey water recycling system redirects grey water from different points to a central recycling unit, where it is filtered. The product can then be used for irrigation outside, greatly cutting fresh water consumption. On a site where there are proposed landscape interventions and food gardens this becomes an economic and environmentally friendly solution.

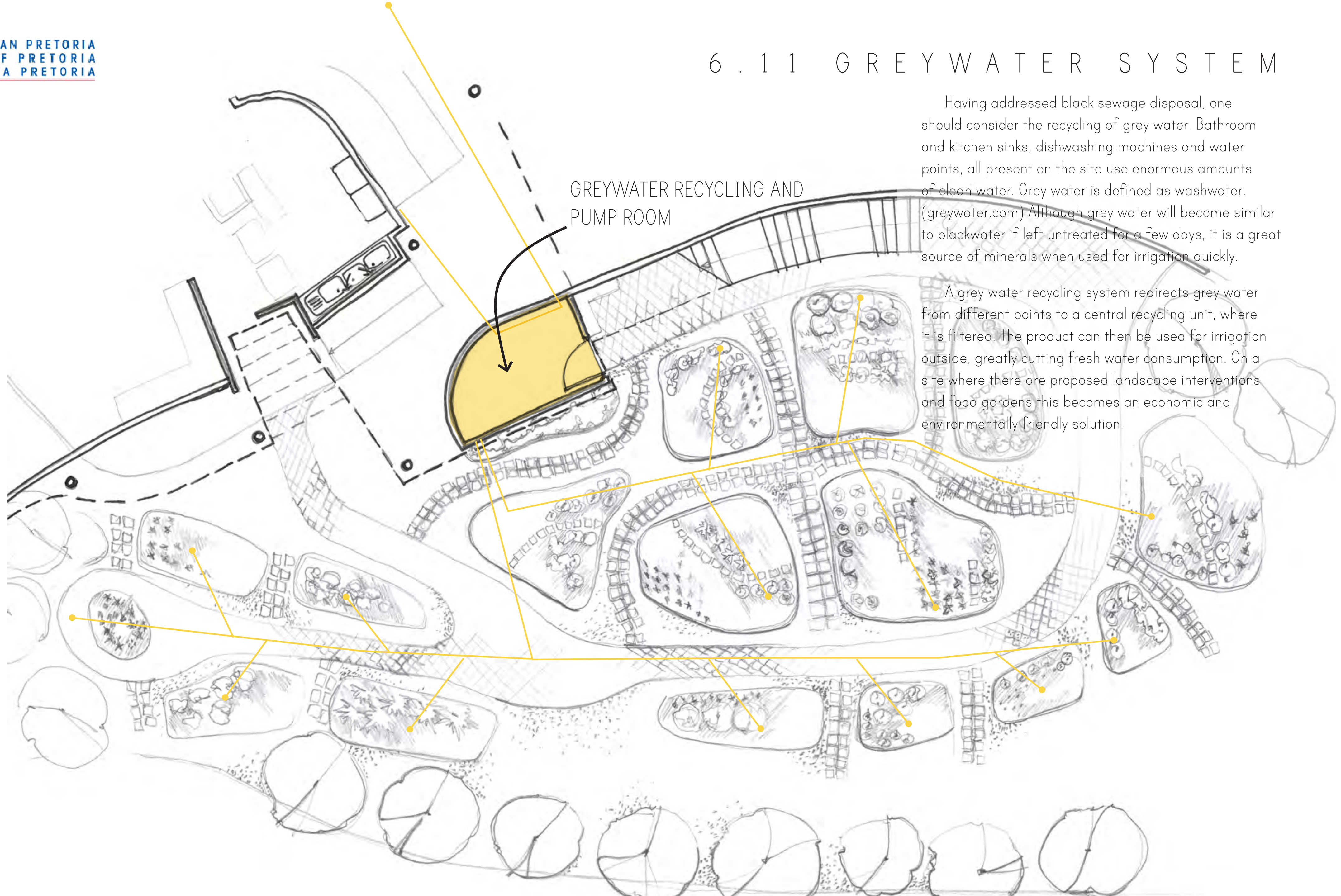


Fig. 306