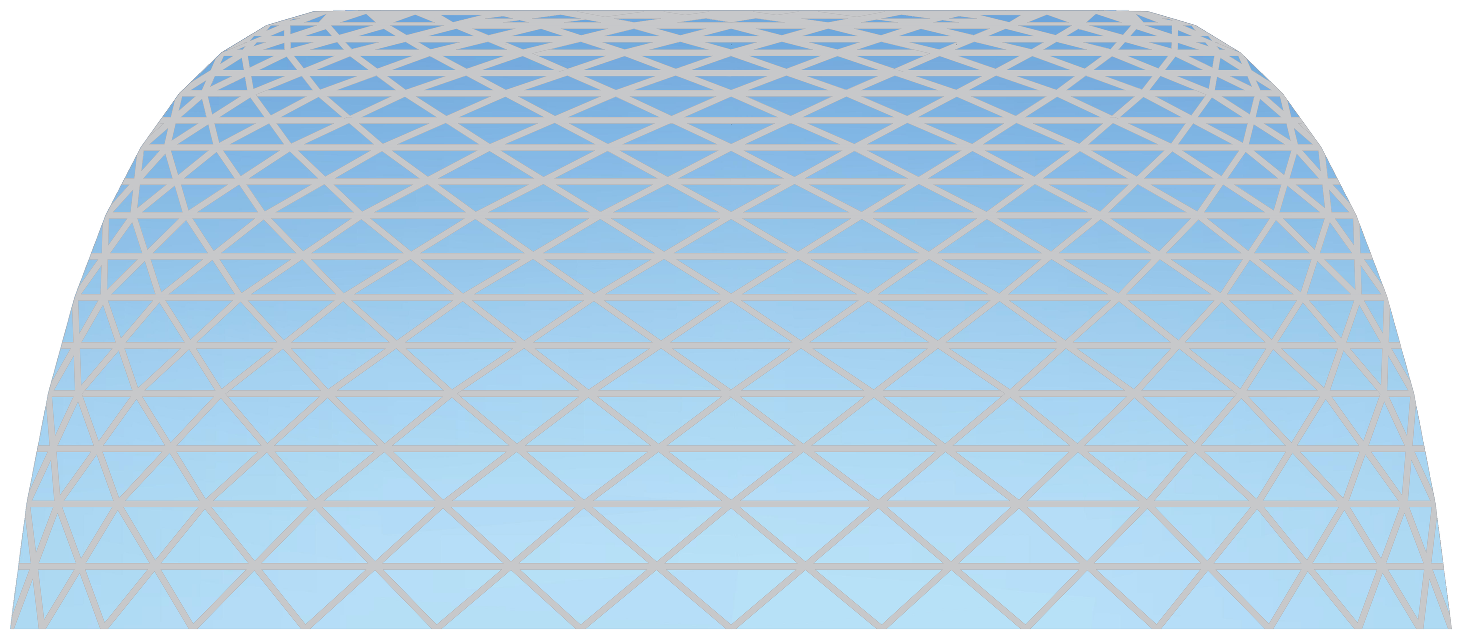
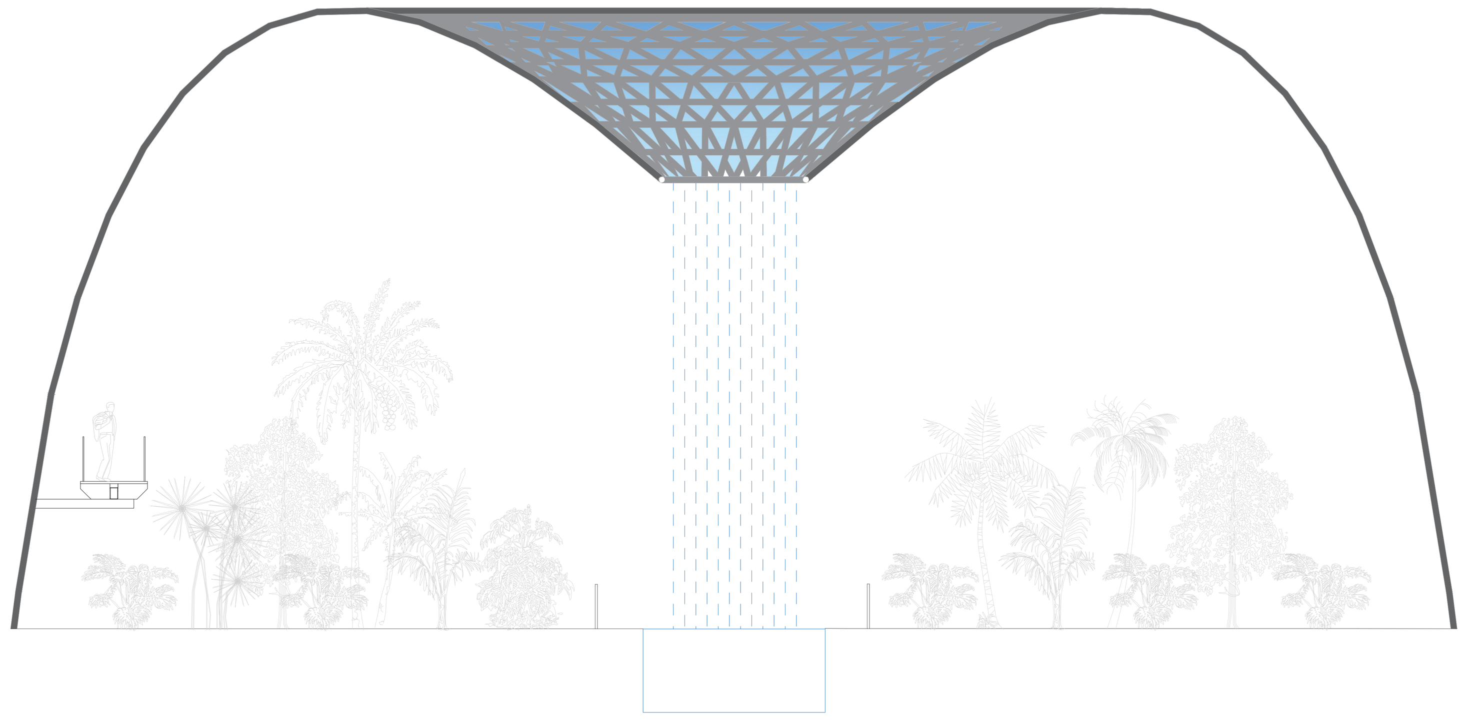
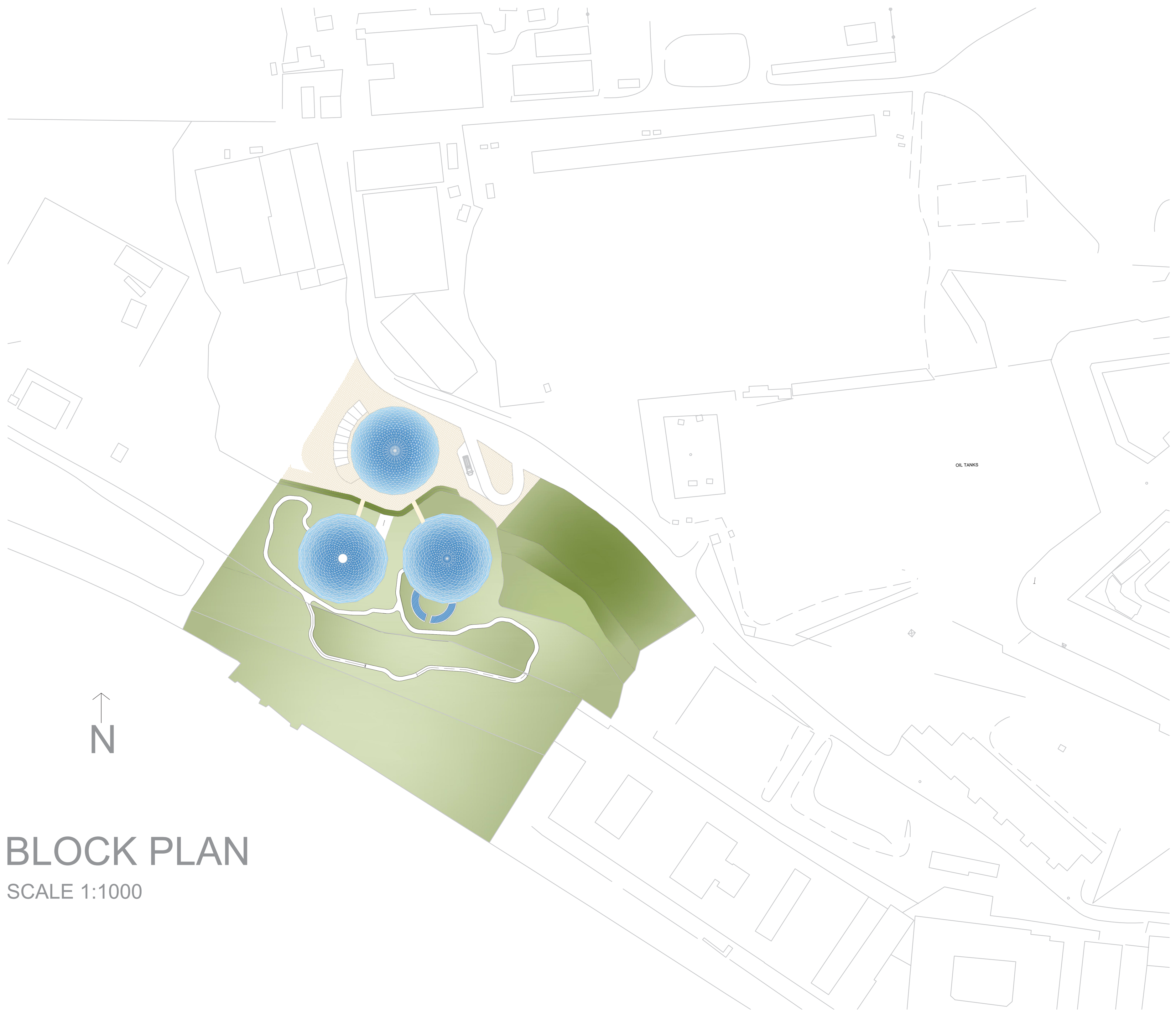
TROPICAL BOTANICAL GARDEN
FINAL YEAR PROJECT

ARCHITECTURAL ELEVATION
SCALE 1:100



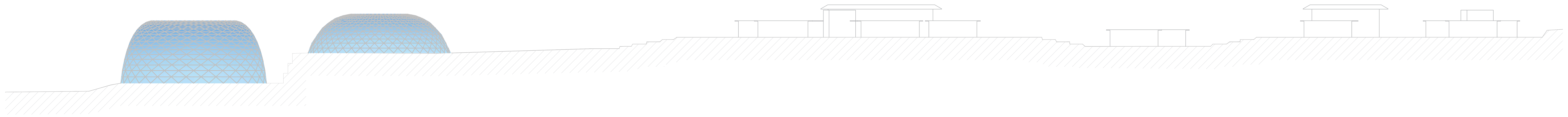
STRUCTURAL SECTION
SCALE 1:100



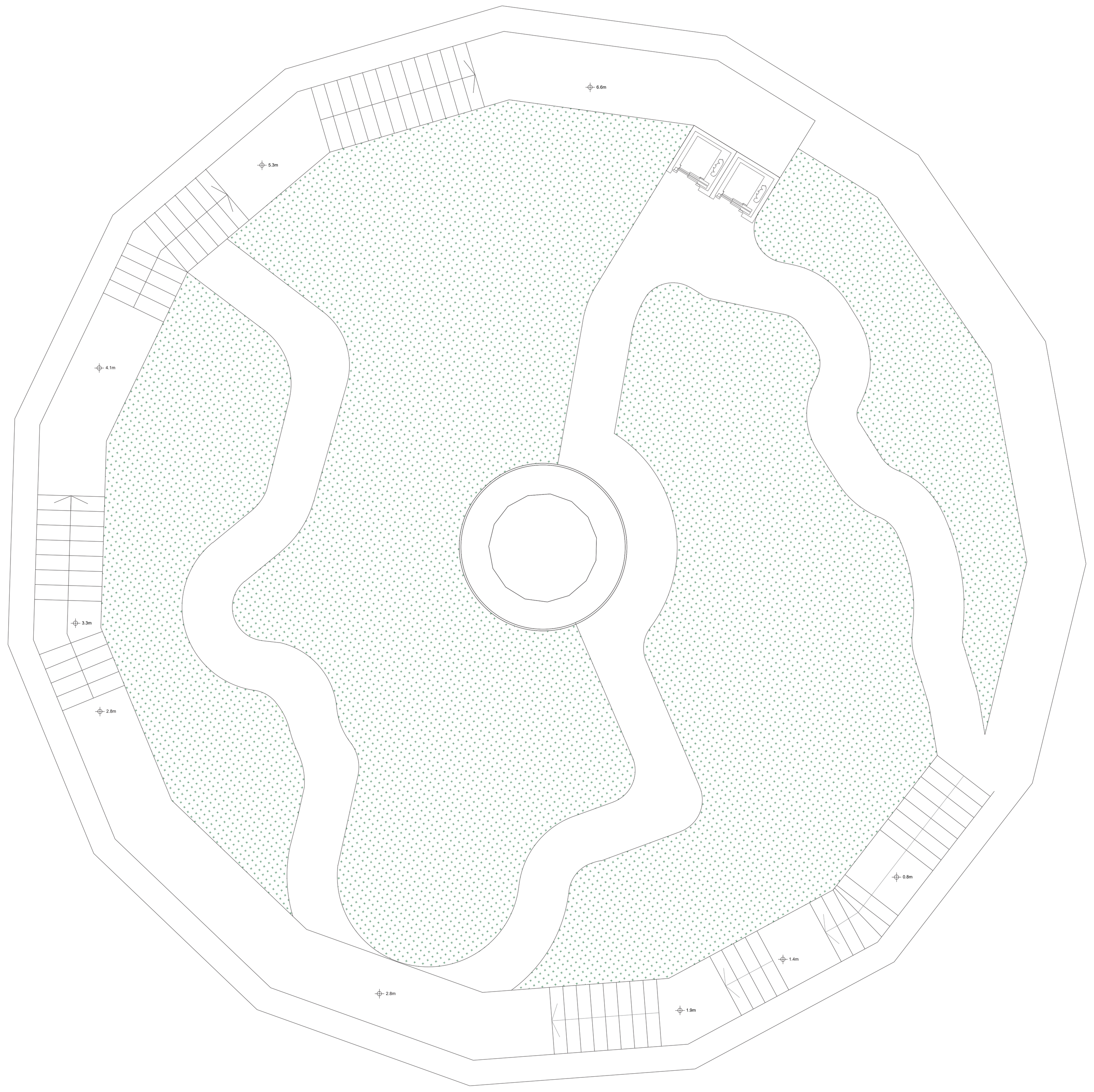


BLOCK PLAN
SCALE 1:1000

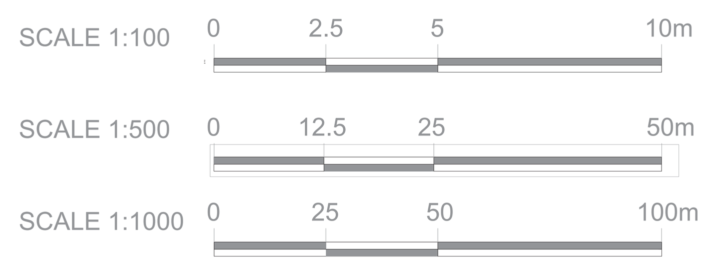
SITE SECTION
SCALE 1:500



RENDER



MAIN ARCHITECTURAL PLAN
SCALE 1:100



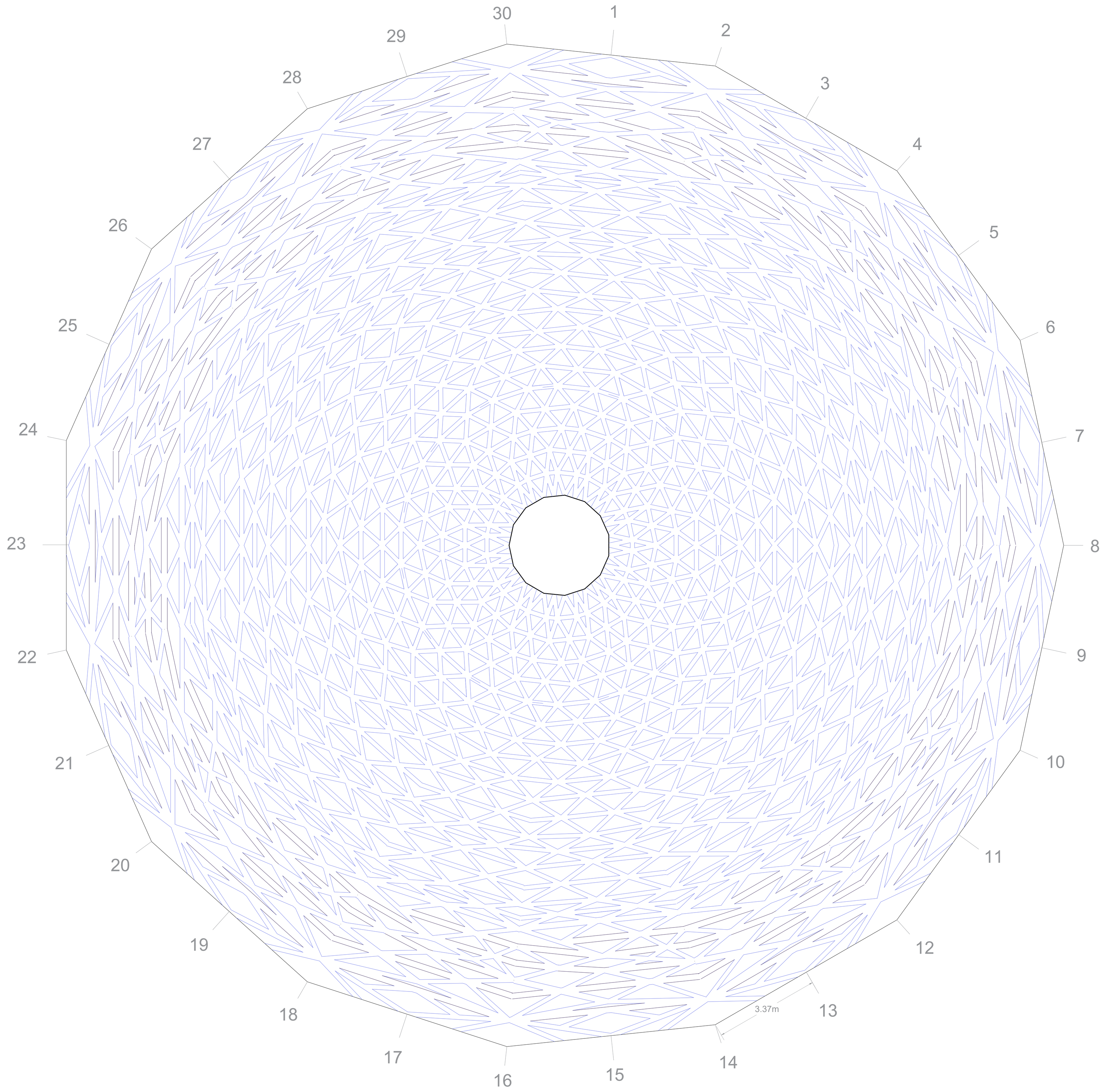
MATTHEW RAPA
0228001L

STRUCTURAL PLAN

SCALE 1:100

CHS 139.7x6.3

CHS 193.7x16



STRUCTURAL ELEVATION

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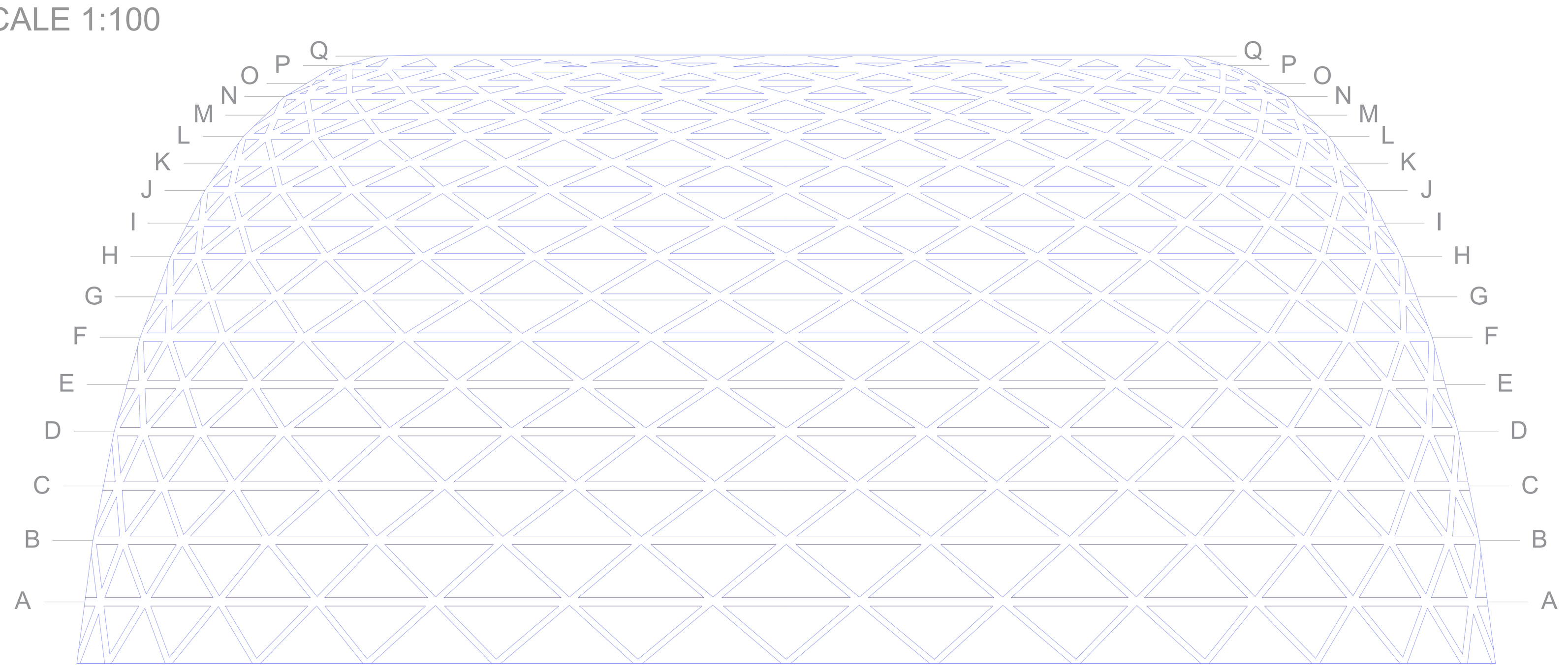
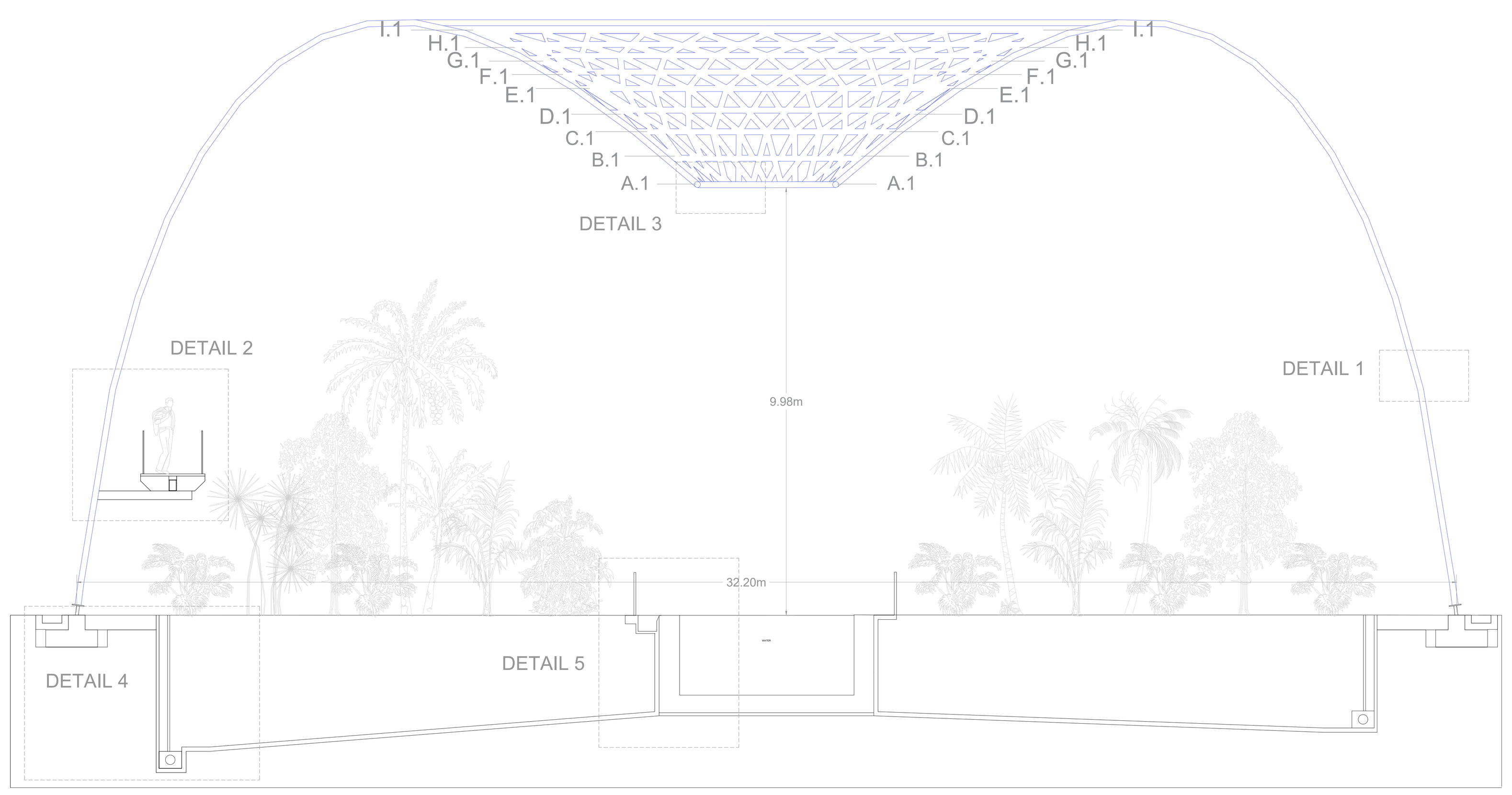


STRUCTURAL SECTION

SCALE 1:100

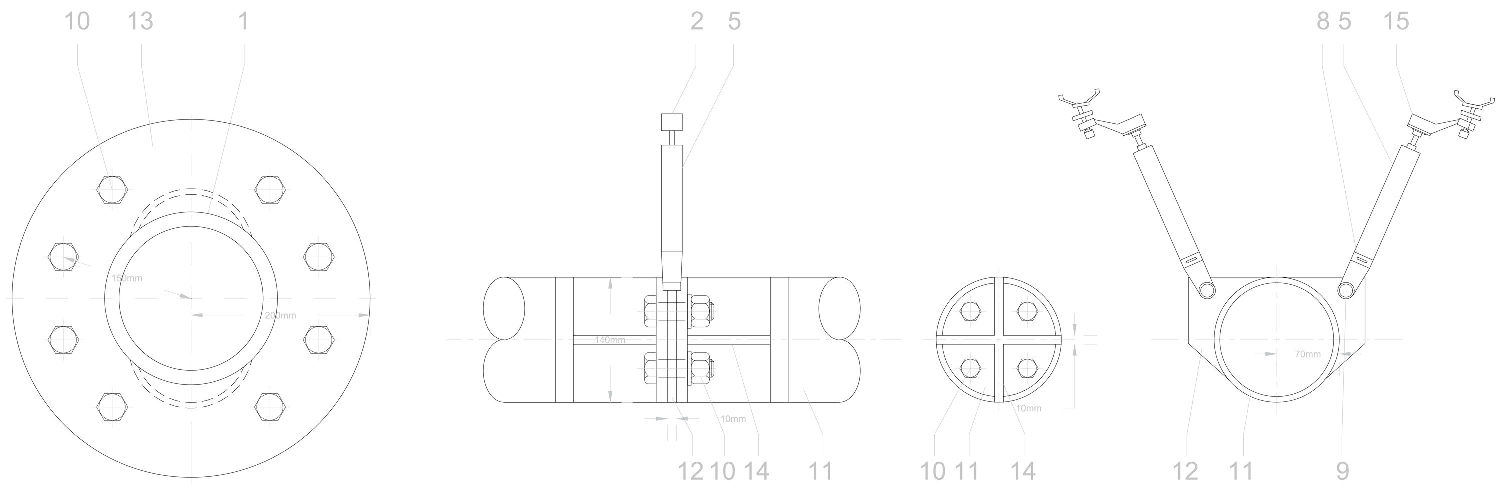


DETAILS

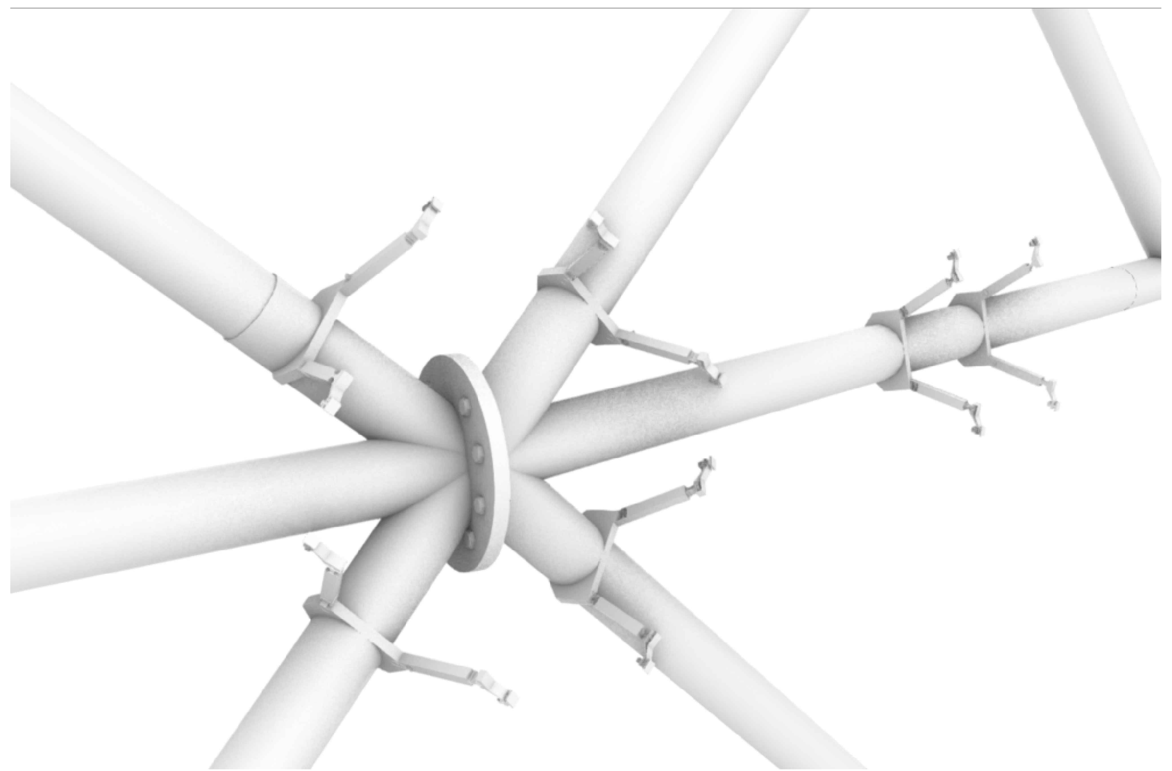
1. GLASS DETAIL

1.1 NODE SPLICES AND SPIDER GLASS ATTACHMENT

SCALE 1:5

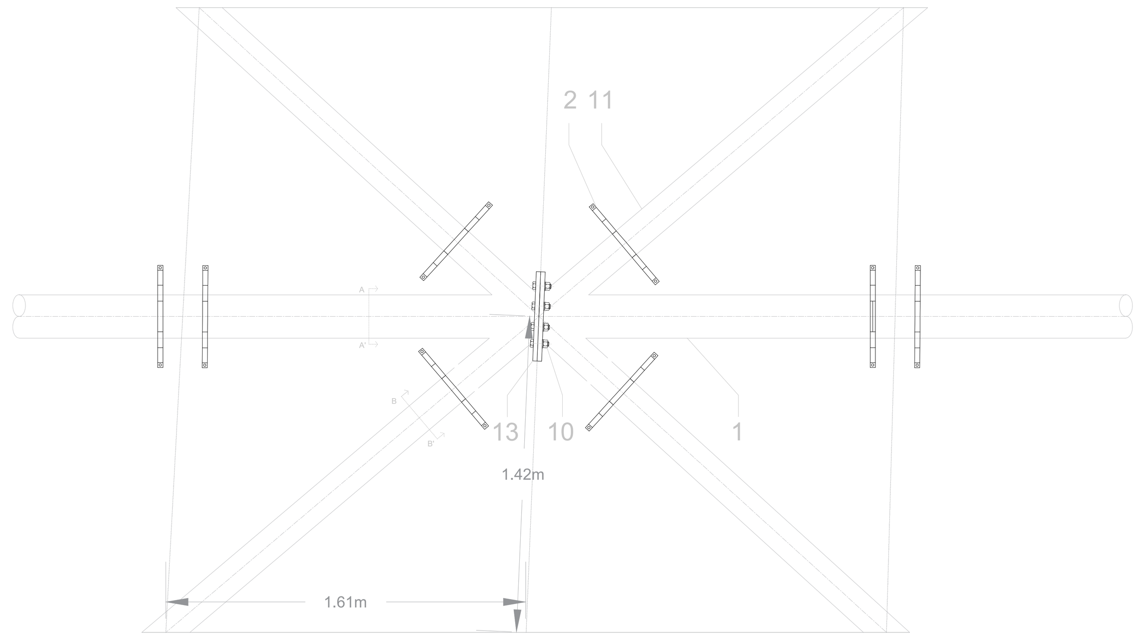


1.2 3D VIEW CONNECTION



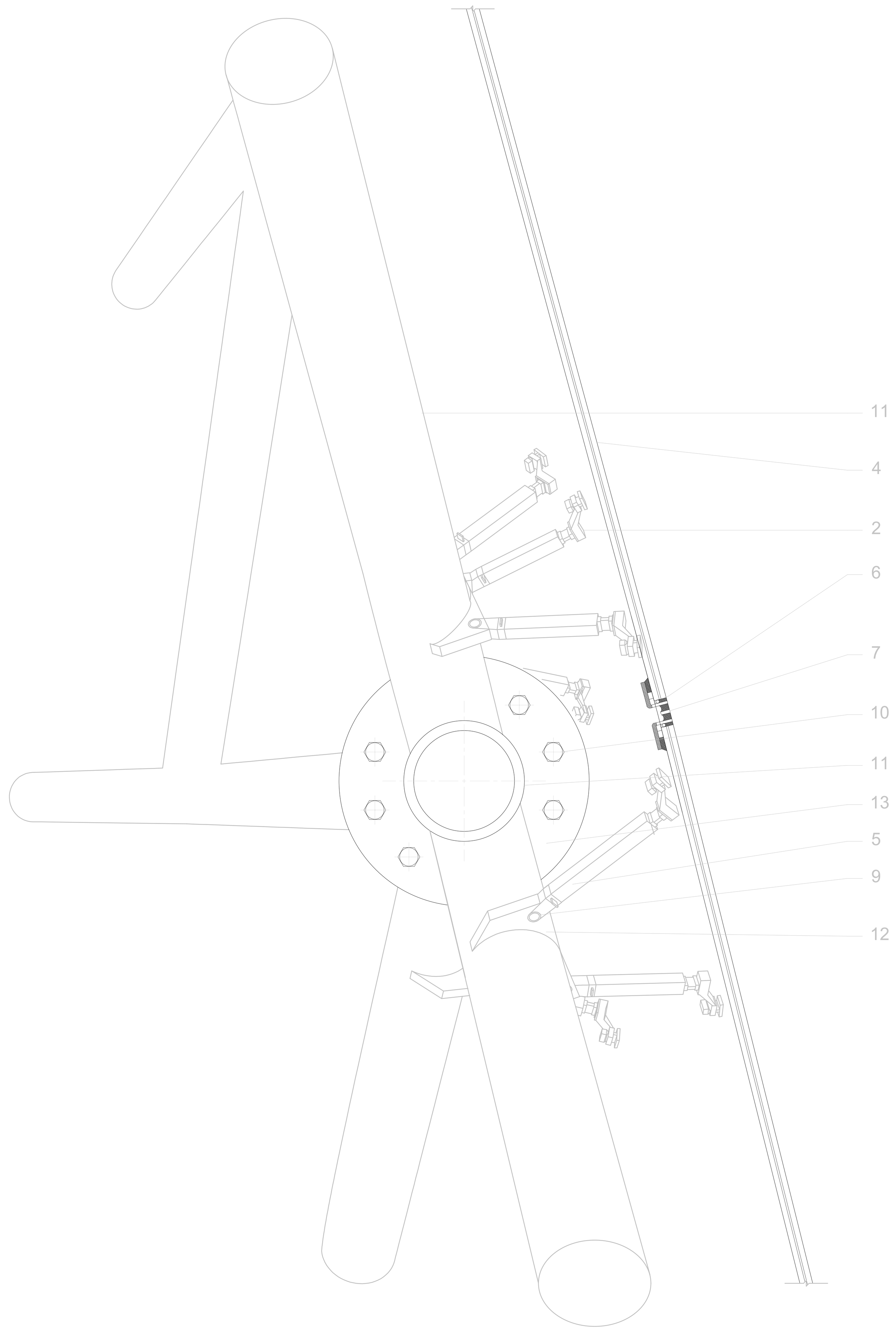
1.3 ELEVATION

SCALE 1:20



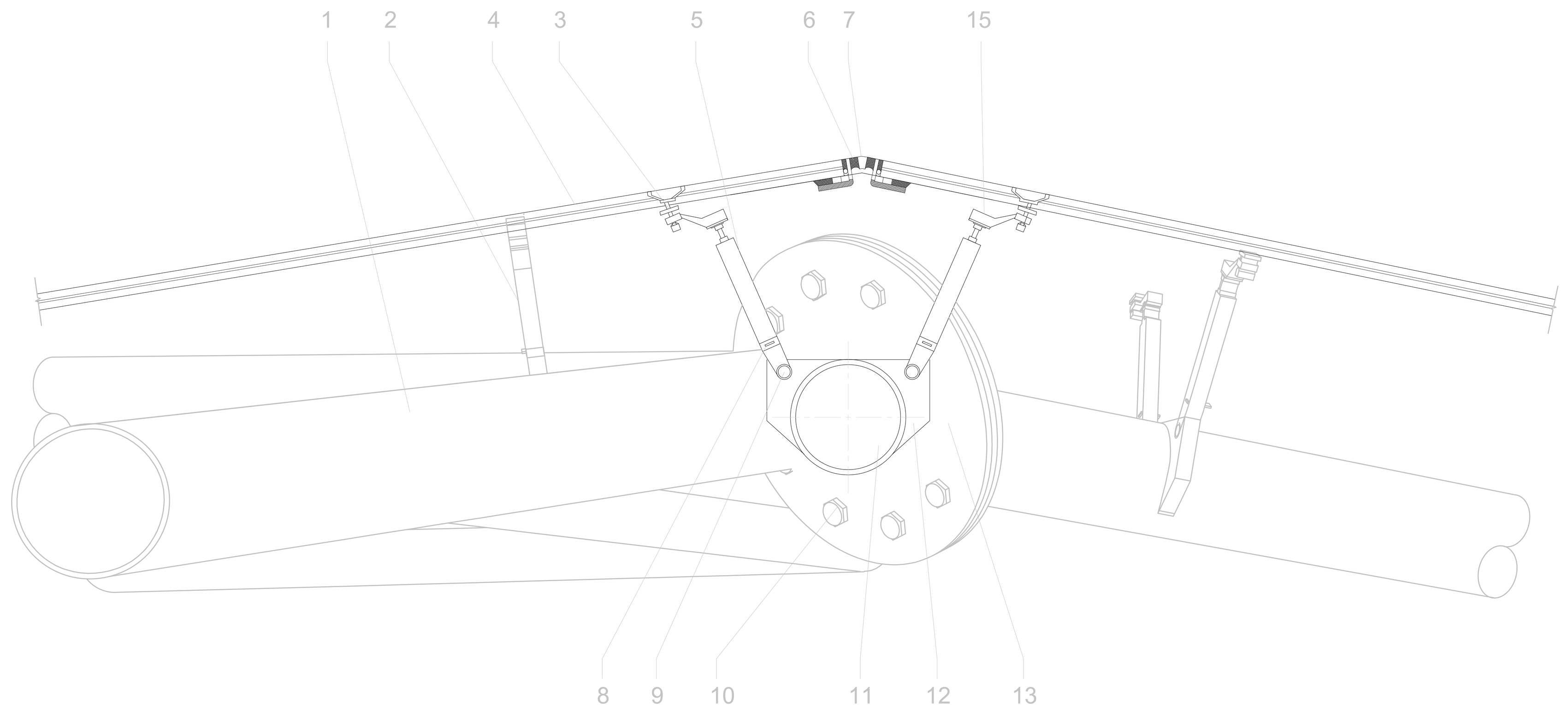
1.4 SECTION A-A'

SCALE 1:5



1.5 SECTION B-B'

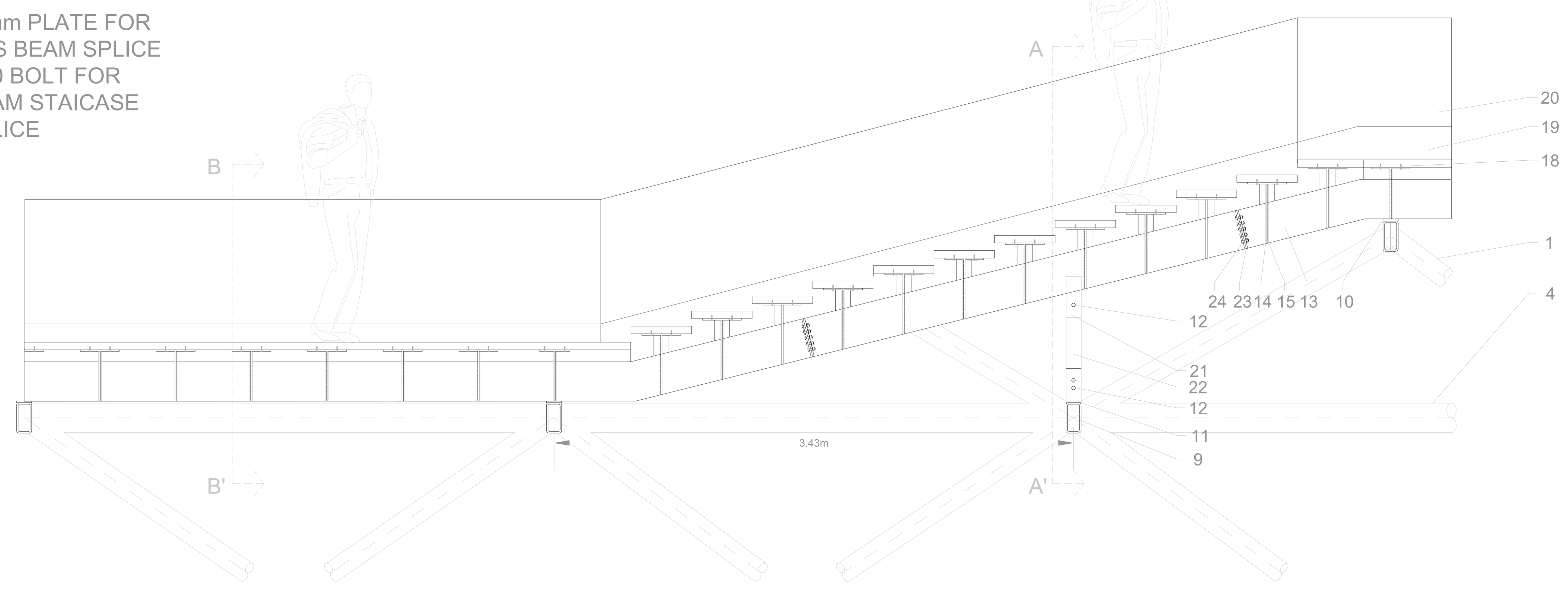
SCALE 1:5



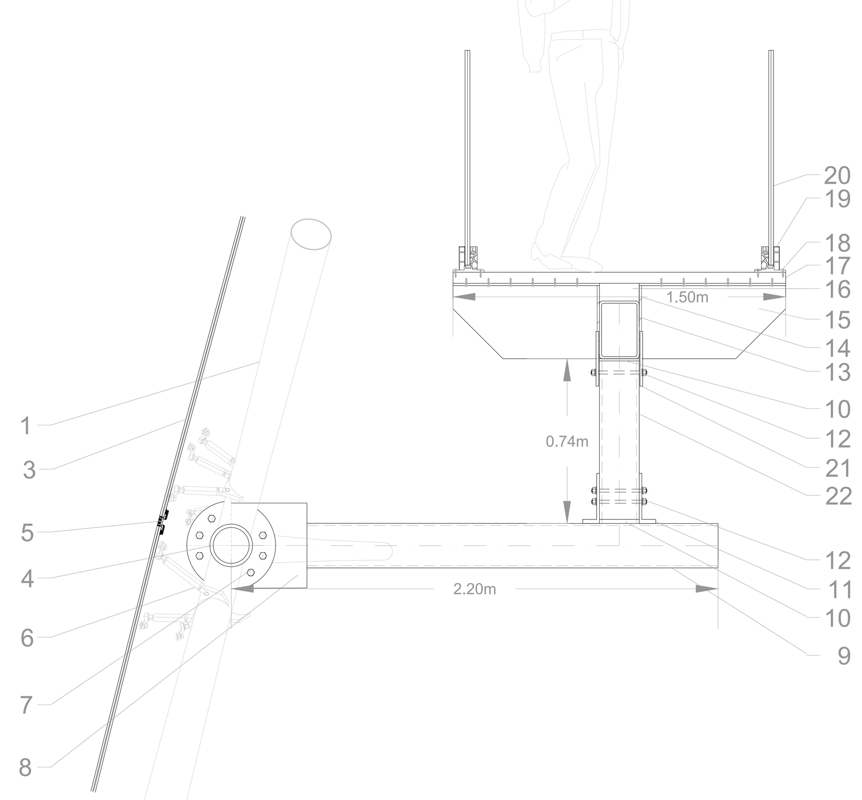
1. CHS 193.7x16mm S355 SECTION WITH C5 ANTI CORROSIVE COATINGS
2. SPIDER GLASS
3. SCREW BOLT FOR SPIDER GLASS CONNECTION
4. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
5. METAL PROP TO CONTROL HEIGHT OF GLASS
6. SILICON SEAL
7. EXTRUDED SILICON SEAL
8. KEY TO TIGHTEN PIN CONNECTION
9. PIN CONNECTION
10. M20 G8.8 BOLTS FOR NODE SPLICE
11. CHS 139.7X6.3 S355 WITH C5 ANTI CORROSIVE COATINGS
12. S355 5mm THICK PLATE FOR SPIDER GLASS CONNECTION
13. DIAM. 400mm S355 PLATE FOR NODE CONNECTION
14. 10mm STIFFENER
15. SPIDER GLASS FITTING

2. CANTILEVERED STAIRS DETAIL

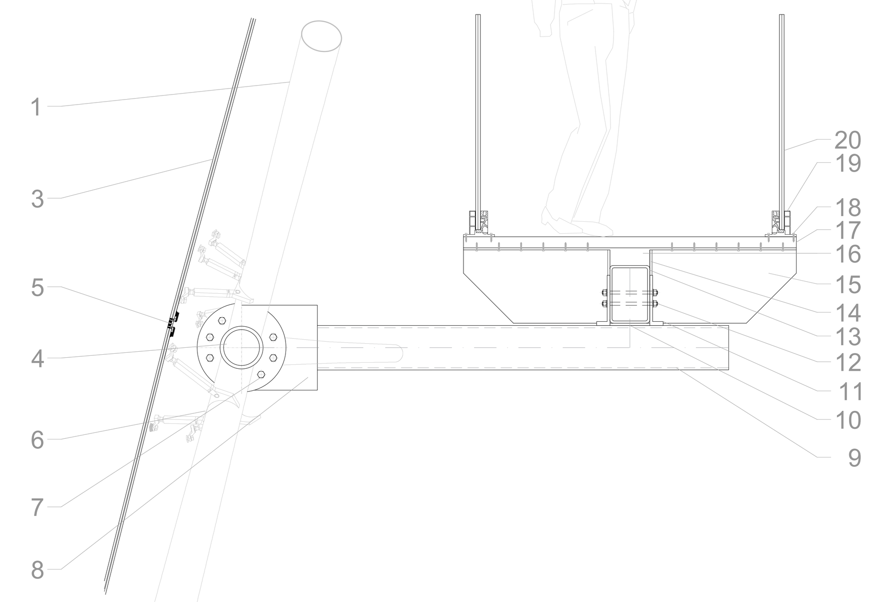
1. CHS SECTION S355 139.7x6.3
2. CHS SPLICE
3. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
4. CHS SECTION S355 193.7x16
5. SILICON SEAL
6. NODE SPLICE DIAM. 400mm S355 STEEL PLATE
7. M20 G8.8 BOLT
8. CROCODILE NODE 30mm S355 PLATE-RHS CONNECTION
9. CANTILEVERED BEAM S355 RHS 200x100x10
10. SHIMS
11. S355 WEB CLEATS WELDED TO BEAM
12. 180mm M20 THROUGH BOLTS
13. S355 RHS 260x180x6.3 STAIRCASE BEAM
14. 10mm WELD BETWEEN STIFFENER AND BEAM (DONE IN PREFABRICATION)
15. S355 10mm STIFFENER
16. STEEL S355 WELDED SPACER
17. 50mm TIMBER STAIRCASE
18. SCREWS
19. GUARD RAIL
20. GLASS RAILING
21. S355 WEB PLATE PRE WELDED TO RHS STAIRCASE BEAM FOR BEAM-COLUMN CONNECTION
22. S355 RHS COLUMN SECTION 180x100x12.5
23. 10mm PLATE FOR RHS BEAM SPLICE
24. M20 BOLT FOR BEAM STAICASE SPLICE



2.1 ELEVATION
SCALE 1:20



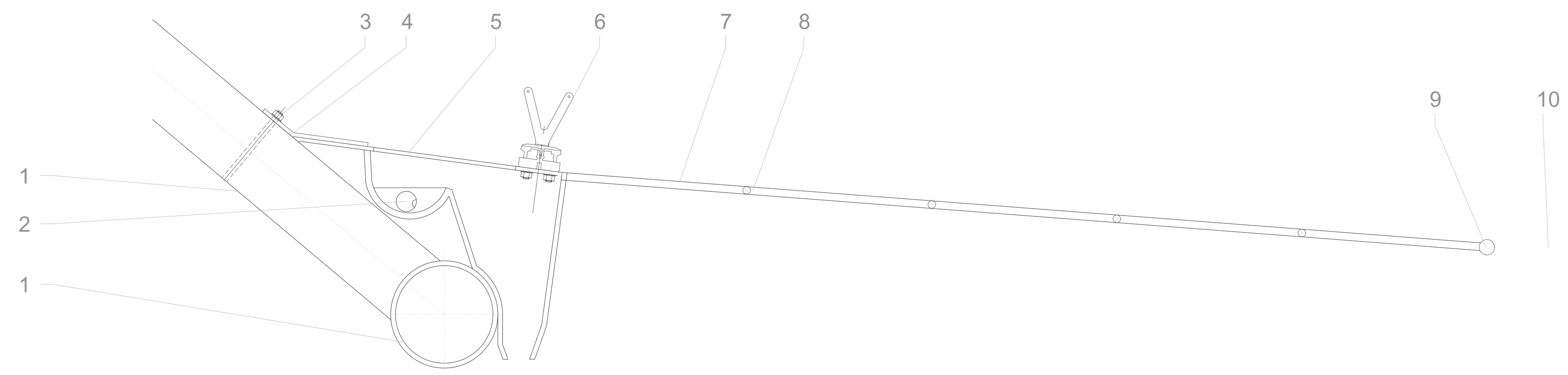
2.2 SECTION A-A'
SCALE 1:20



2.3 SECTION B-B'
SCALE 1:20

3.ROOF DETAIL

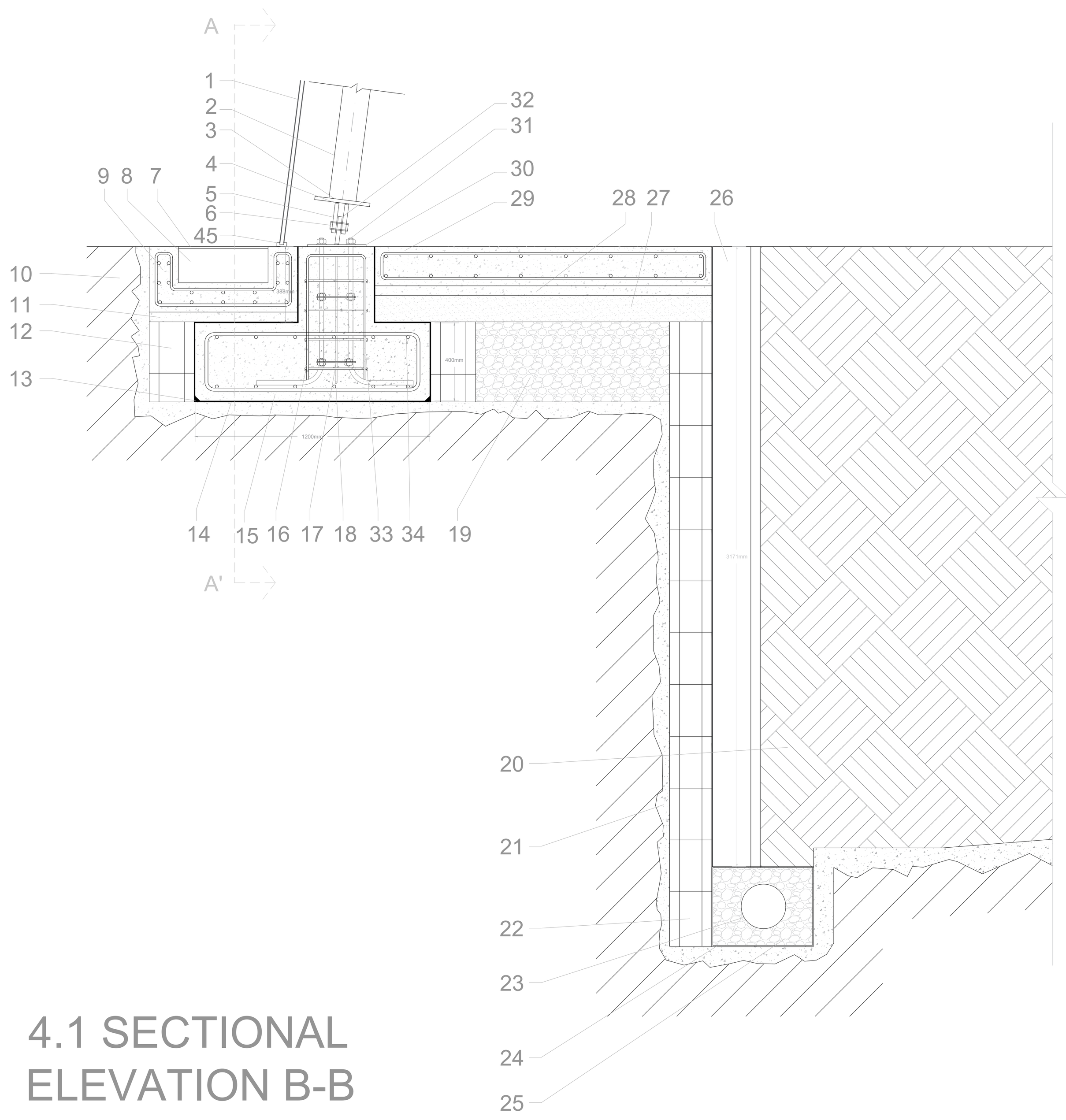
1. CHS 139.7x6.3 S355 SECTION WITH C5 ANTI-CORROSIVE COATING
2. WATER PIPE TO CREATE ARTIFICIAL WATERFALL EFFECT
3. M8 THROUGH BOLT
4. WELDED PLATE BETWEEN ALUMINIUM COVER PLATE AND BEAM
5. ALUMINIUM COVER PLATE WITH FUNNEL TO DIRECT WATER
6. BIRD PROTECTOR
7. PTFE ROOF
8. PURLINS TO SUPPORT PTFE
9. COMPRESSION BEAM TO KEEP PTFE TAUT
10. HOLE TO ALLOW WATER TO PASS THROUGH



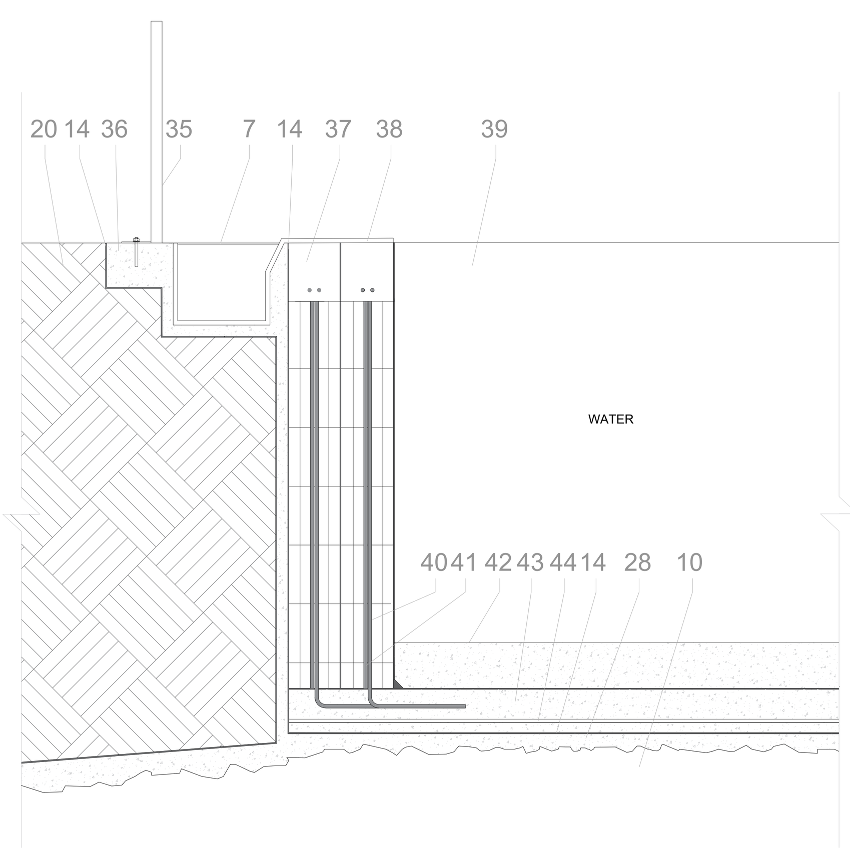
3.1 ELEVATION
SCALE 1:5

4. FOUNDATION DETAIL

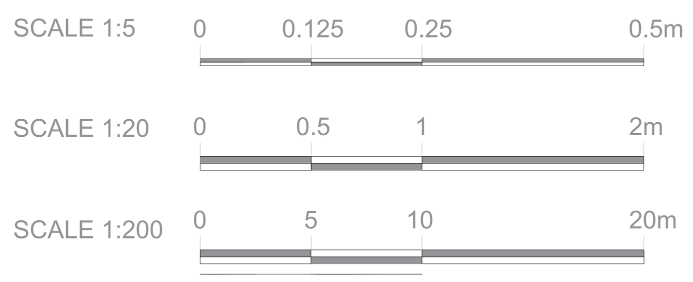
1. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
2. CHS 139.7x6.3 S355 SECTION WITH C5 ANTI-CORROSIVE COATING
3. S355 300x285x17.5mm BASE PLATE
4. 5mm WELD
5. S355 165mm x 220mm x20mm PLATE
6. PIN CONNECTON 40mm DIAM
7. GRILL COVER FOR GUTTER
8. RAINWATER GUTTER
9. PRECAST GUTTER
10. GLOBIGERINA LIMESTONE
11. C15 CONCRETE BLINDING LAYER
12. 230MM HCB BLOCKS
13. SAND-CEMENT WEDGE
14. 5MM TORCH WELDED MEMBRANE
15. C40 CONCRETE STRIP FOOTING
16. T16 HORIZONTAL REINFORCEMENT @150mm SPACING
17. DIVISION PLATE
18. BOTTOM REINFORCEMENT T16 @200MM SPACING
19. GRAVEL FILL
20. ENGINEERED SOIL FOR TROPICAL PLANTS
21. C15 CONCRETE SIDE FILL
22. HCB 230MM CONCRETE BLOCK FOR SOIL-ROCK BARRIER
23. FRENCH DRAIN
24. GEOTEXTILE
25. GRAVEL FILL
26. PVC PIPE FOR RODDING PIPE ACCES
27. ENGINEERED FILL
28. C15 BLINDING LAYER
29. 200MM PRECAST SLAB
30. S355 FOUNDATION BASE PLATE
31. M20 J-BOLT
32. WELDED S355 CONNECTING BASE PLATE TO FOUNDATION
33. T16 TIES
34. TOP REINFORCMENT T16 @200mm SPACING
35. BARRIER FOR RESERVOIR
36. C20 200mm CONCRETE SLAB
37. BOND BEAM
38. CERAMIC TILING
39. WATER FROM WATER FEATURE
40. T16 REBAR REINFORCEMENT
41. T16 REBAR REINFORCEMENT LAPPED
42. 200mm GROUND SLAB
43. 200mm C30 IN-SITU SLAB
44. A503 MESH
45. RUBBER GLAZING GASKET

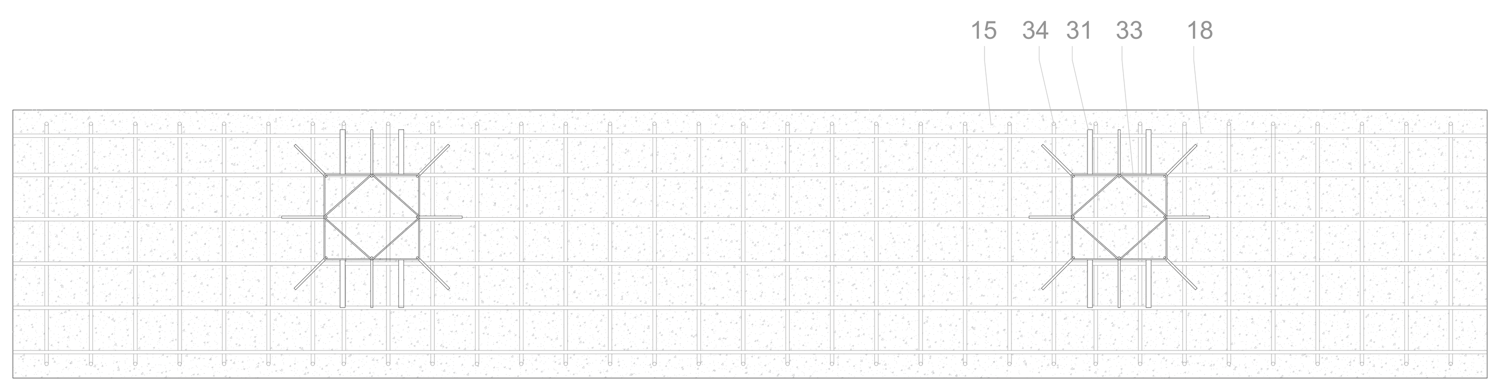


4.1 SECTIONAL ELEVATION B-B
SCALE 1:20

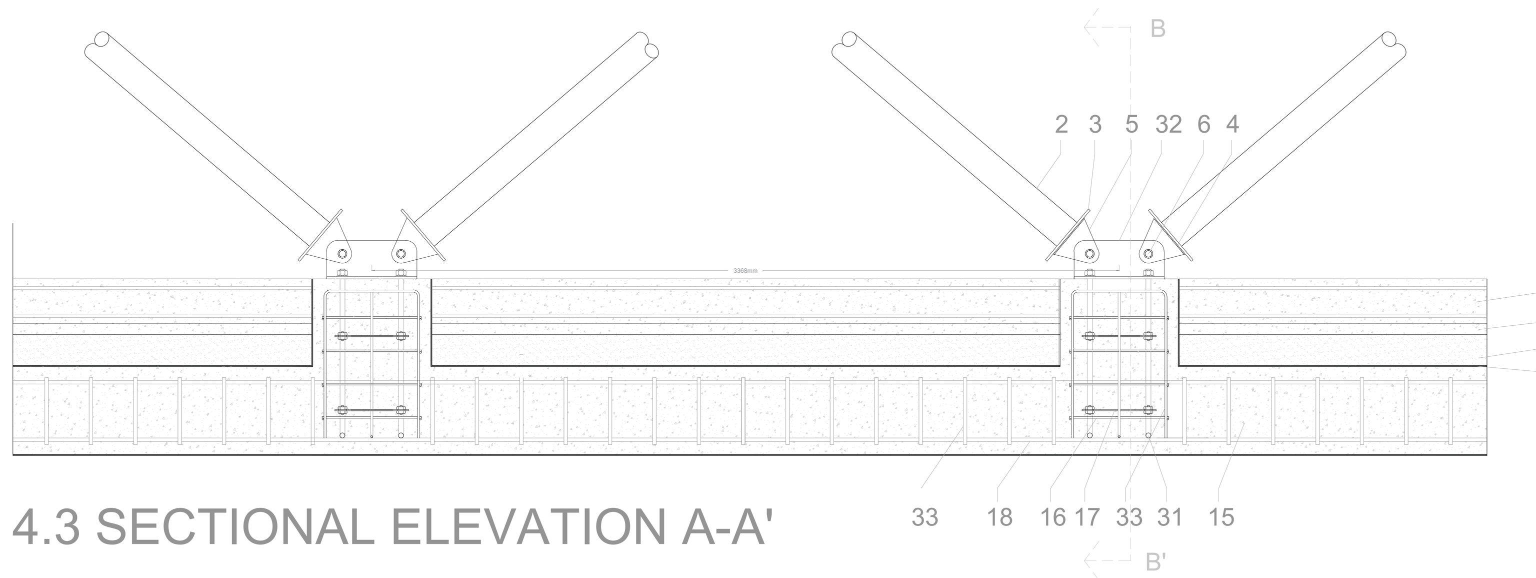


5. RESERVOIR DETAIL

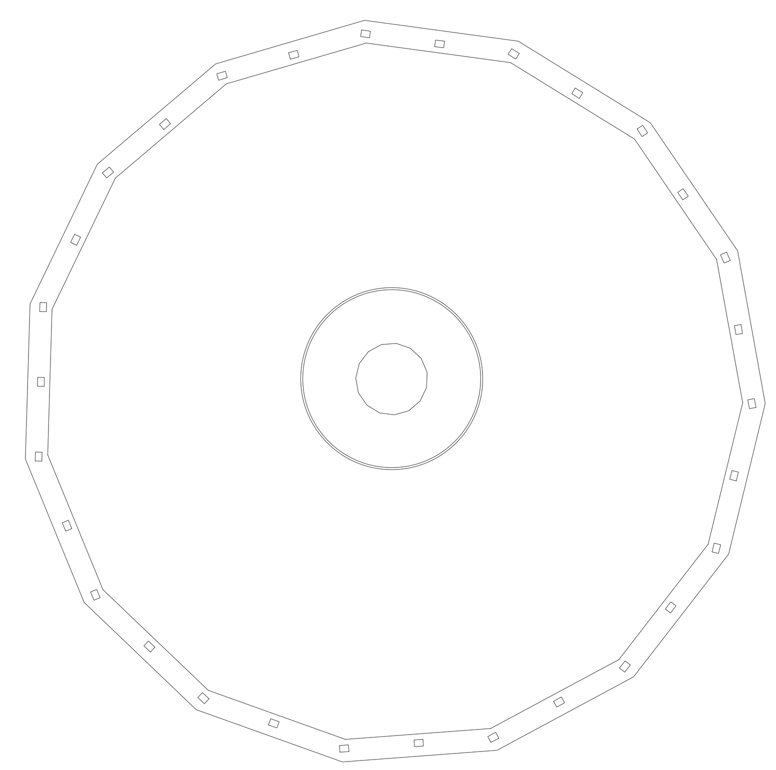




4.2 SECTIONAL PLAN
SCALE 1:20



4.3 SECTIONAL ELEVATION A-A'
SCALE 1:20



4.4 FOUNDATION PLAN
SCALE 1:100

PORTFOLIO
OF DRAWINGS

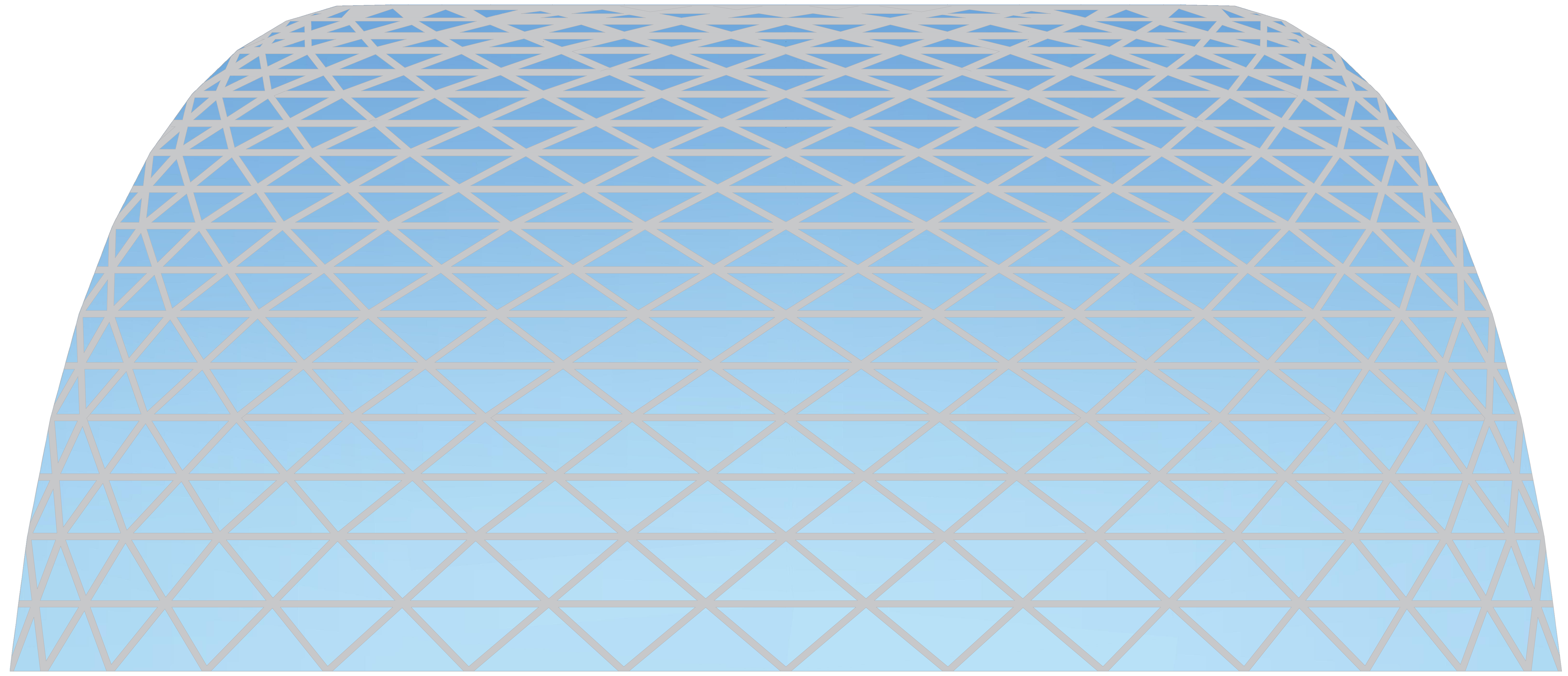
BLOCK PLAN

N

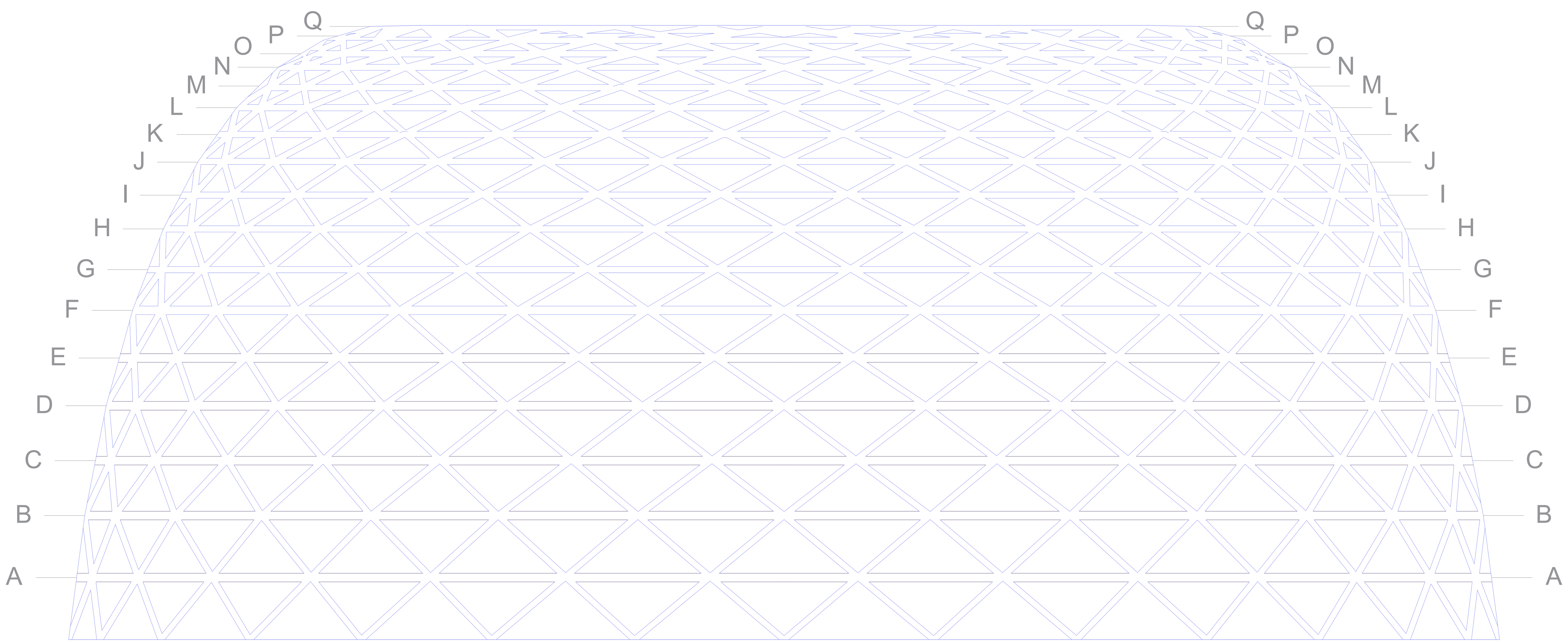
SCALE 1:2500

0 5 10 20m

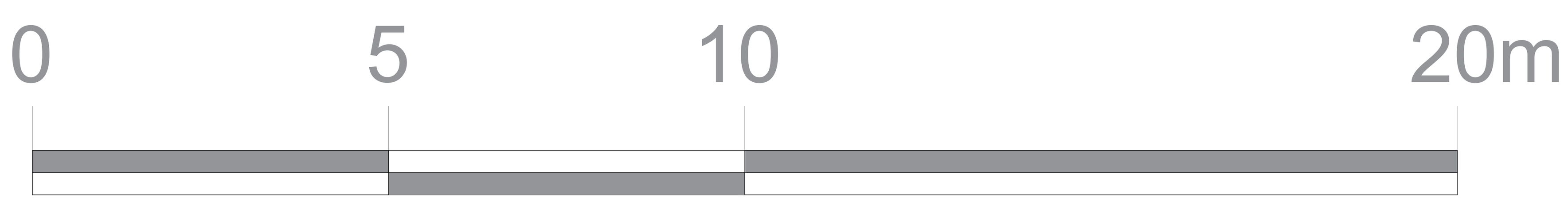
ARCHITECTURAL ELEVATION



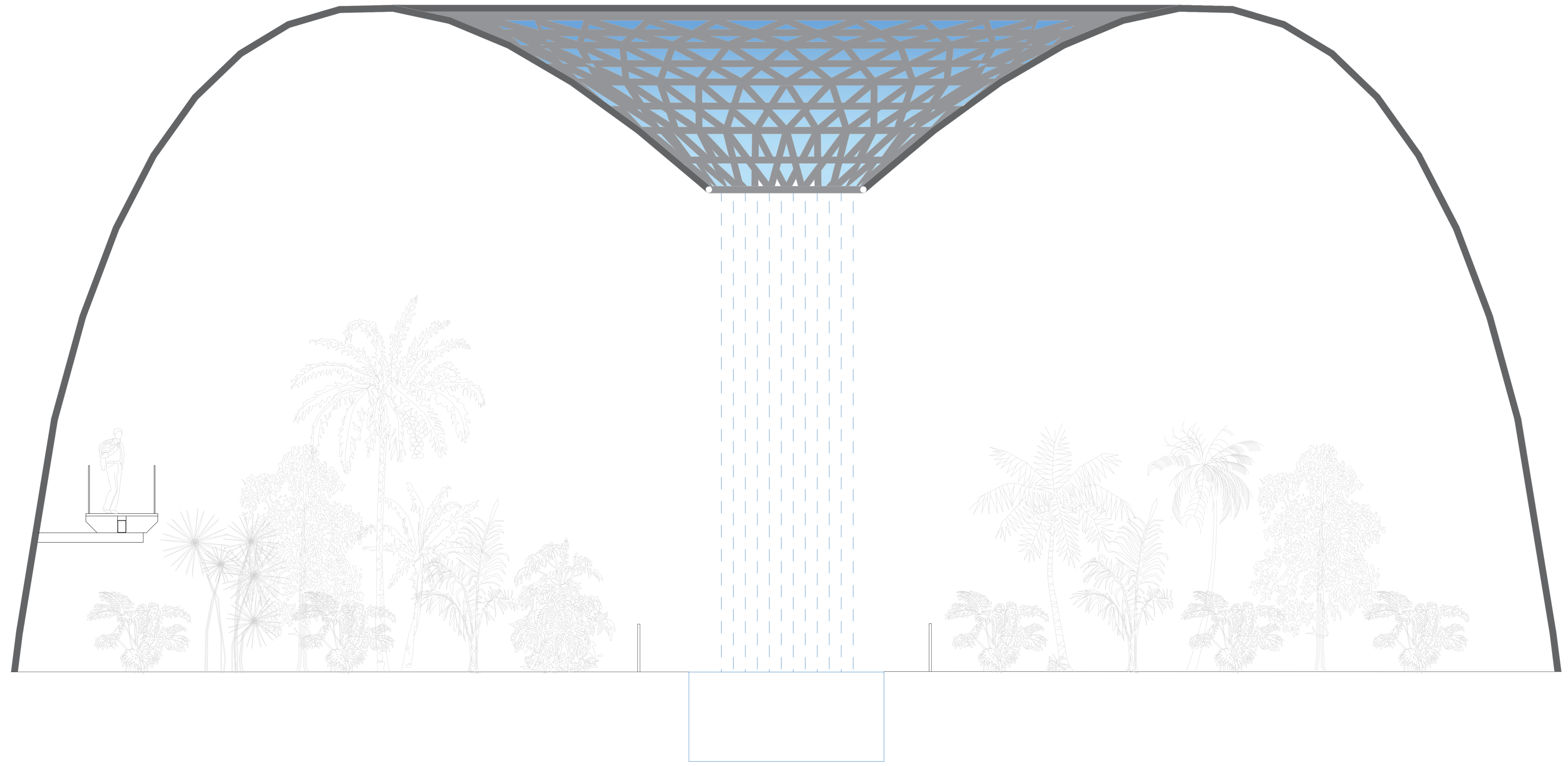
STRUCTURAL ELEVATION



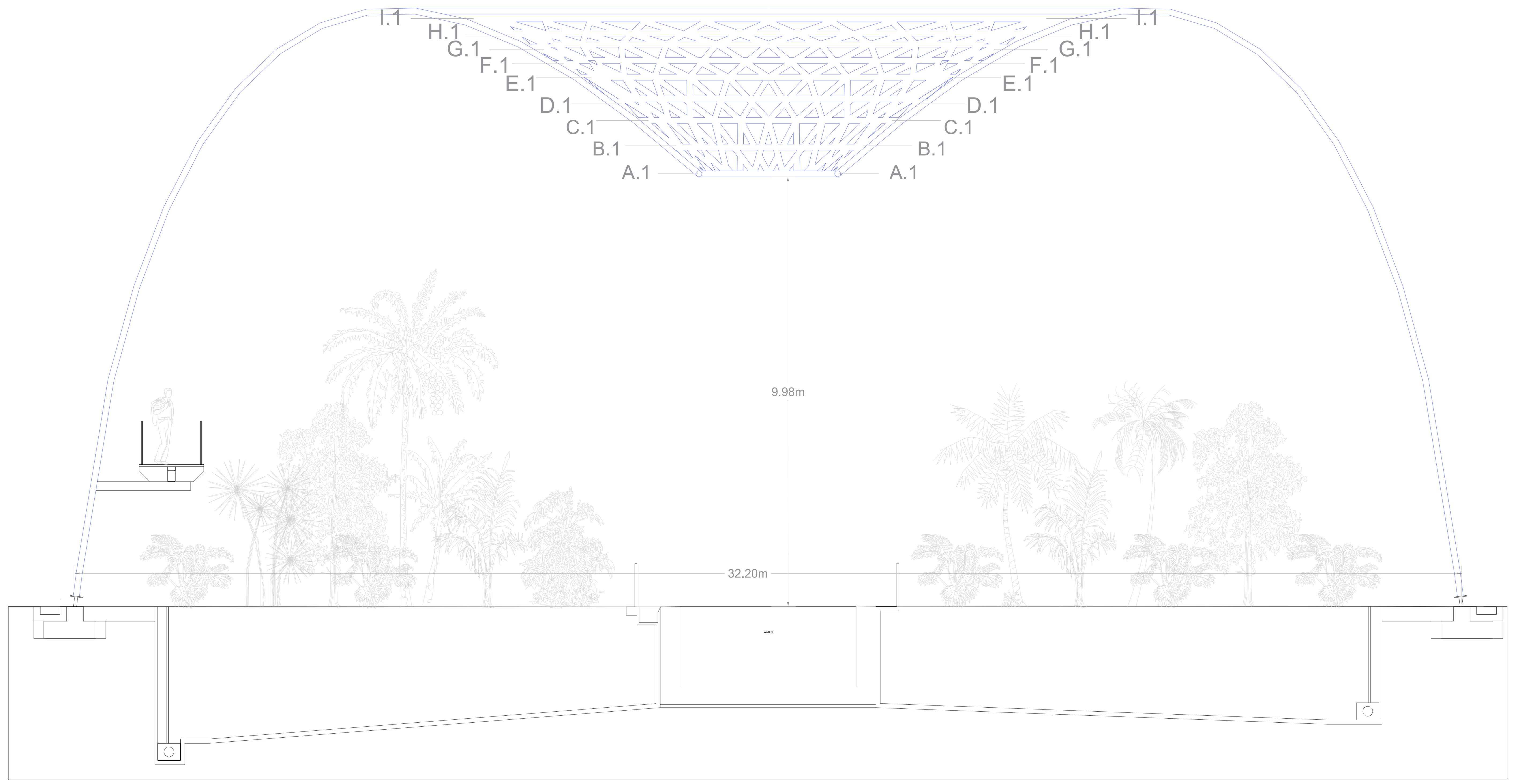
SCALE 1:200



ARCHITECTURAL SECTION



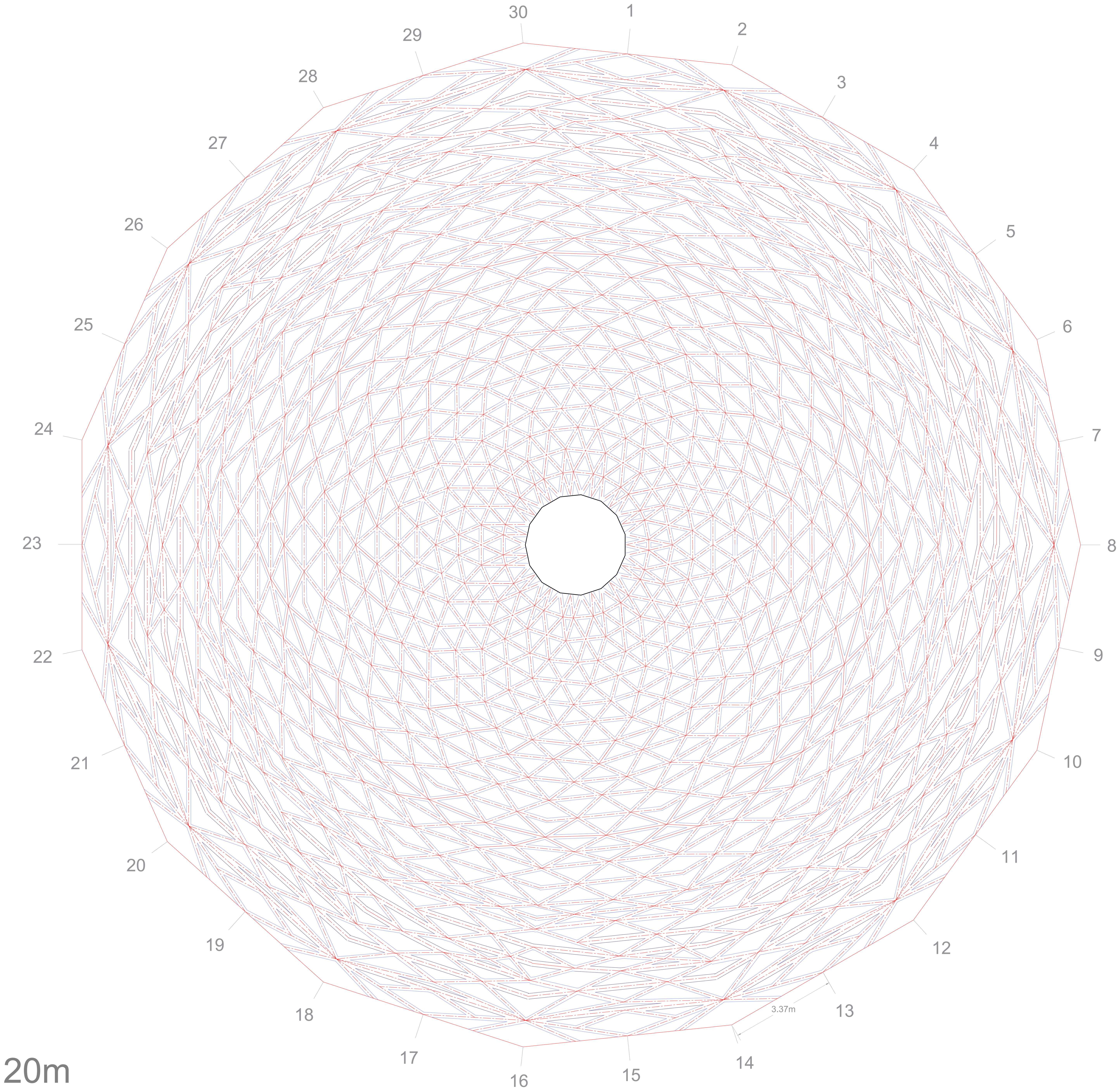
STRUCTURAL SECTION



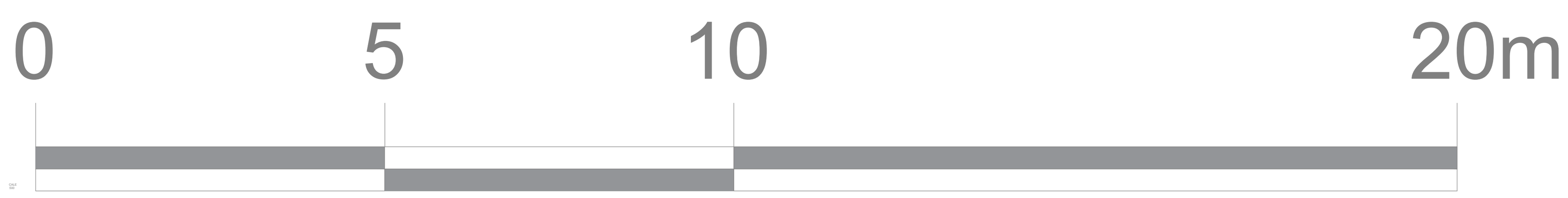
SCALE 1:200

0 5 10 20m

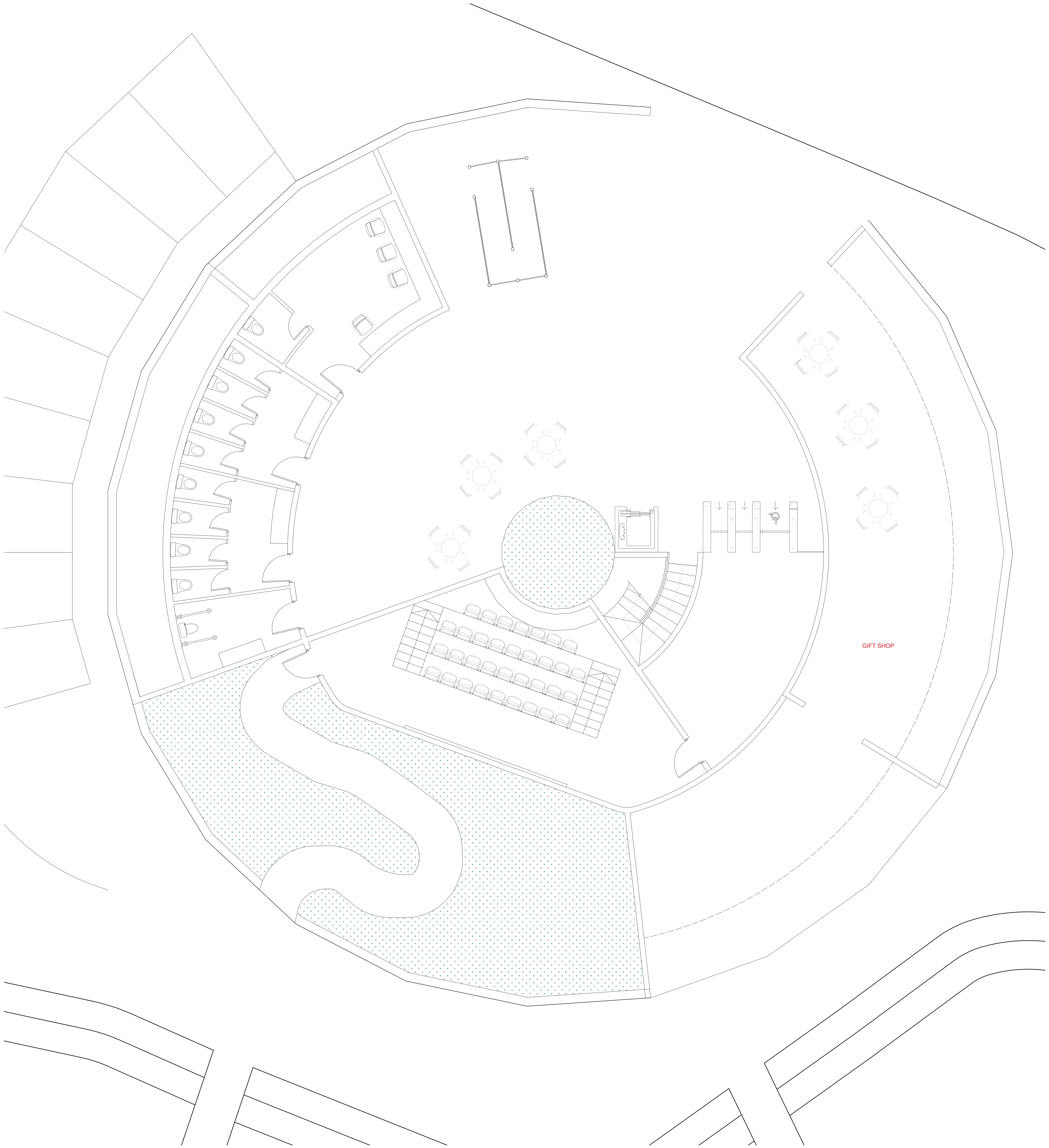
STRUCTURAL PLAN



SCALE 1:200



FIRST STRUCTURE PLAN



SCALE 1:200

0 5 10 20m

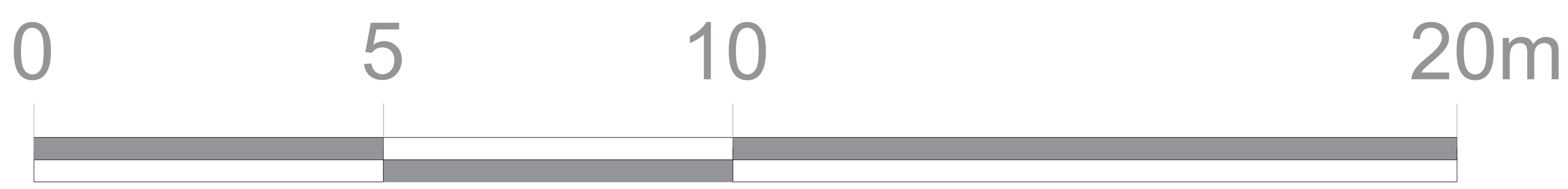
SECOND STRUCTURE PLAN

SCALE 1:200

0 5 10 20m

THIRD STRUCTURE PLAN

SCALE 1:200



GLASS DETAIL

SCALE 1:50

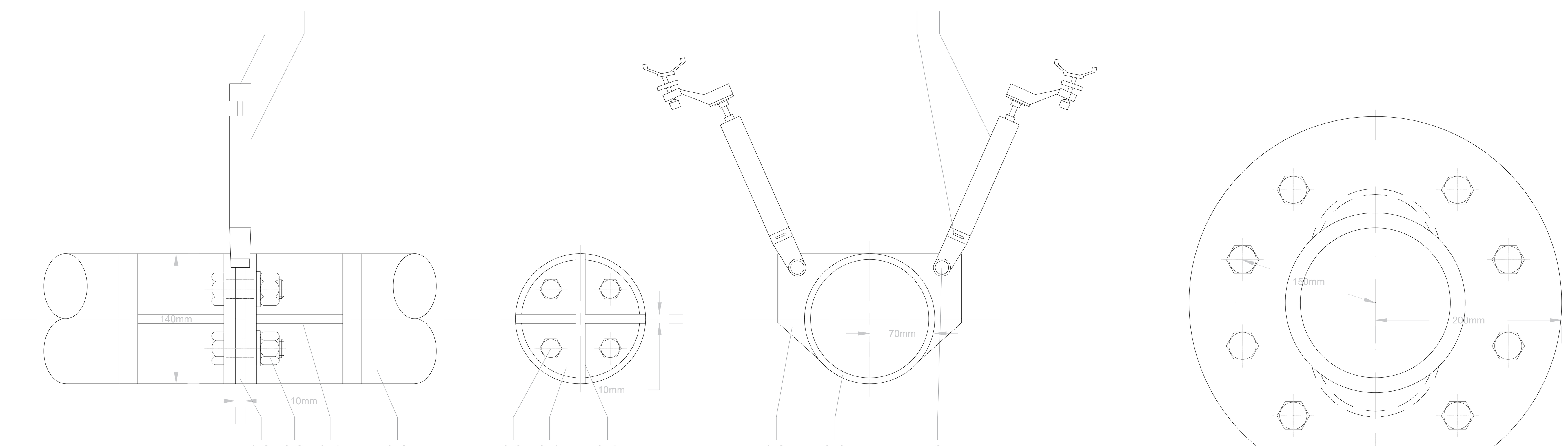
0 1.25 2.5 5m

SCALE 1:10

0 0.125 0.25 0.5m

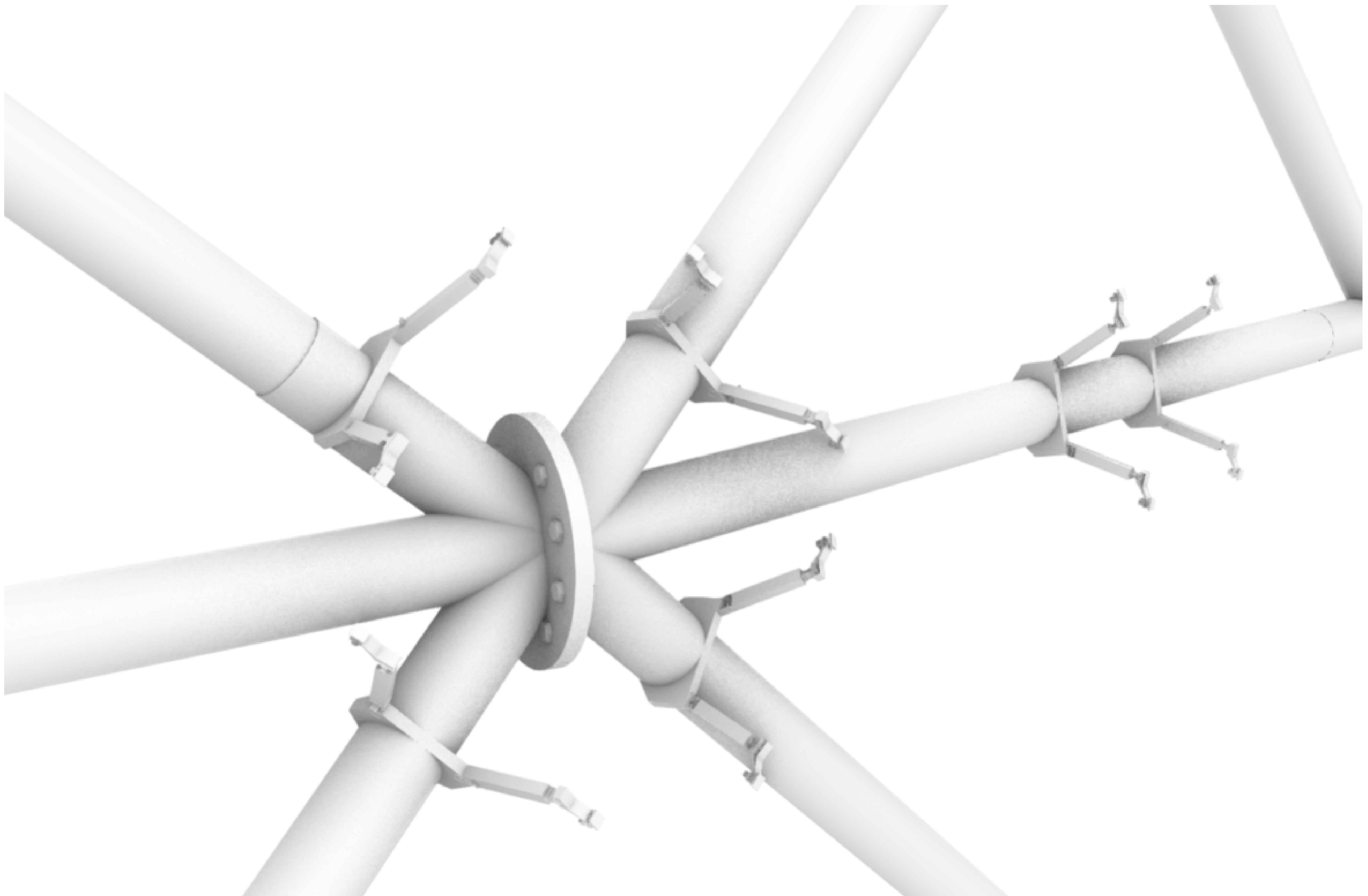
NODE CONNECTIONS

SCALE 1:50



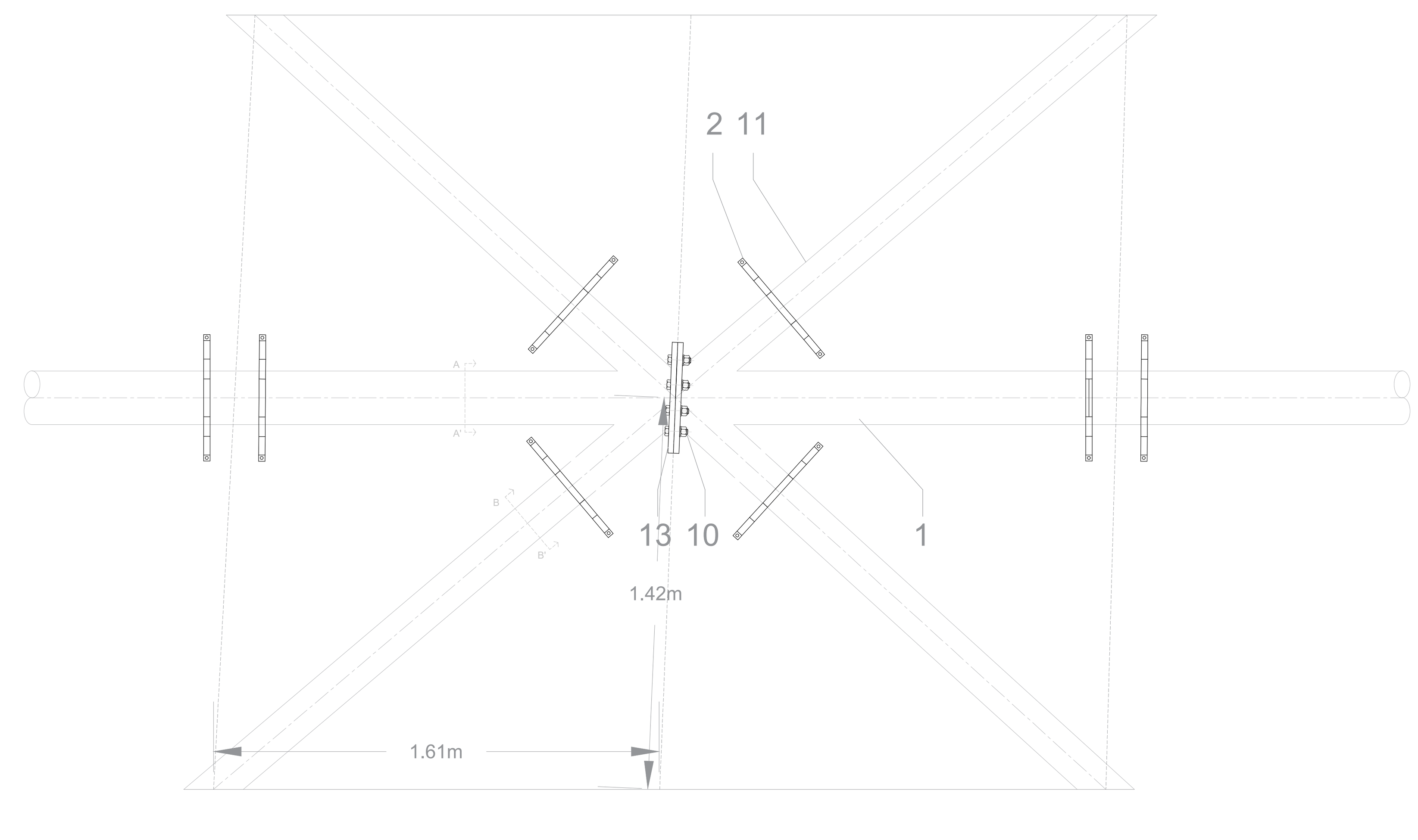
1. CHS 193.7x16mm S355 SECTION WITH C5 ANTI CORROSIVE COATINGS
2. SPIDER GLASS
3. SCREW BOLT FOR SPIDER GLASS CONNECTION
4. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
5. METAL PROP TO CONTROL HEIGHT OR GLASS
6. SILICON SEAL
7. EXTRUDED SILICON SEAL
8. KEY TO TIGHTEN PIN CONNECTION
9. PIN CONNECTION
10. M20 G8.8 BOLTS FOR NODE SPLICE
11. CHS 139.7X6.3 S355 WITH C5 ANTI CORROSIVE COATINGS
12. S355 5mm THICK PLATE FOR SPIDER GLASS CONNECTION
13. DIAM. 400mm S355 PLATE FOR NODE CONNECTION
14. 10mm STIFFENER
15. SPIDER GLASS FITTING

3D VIEW

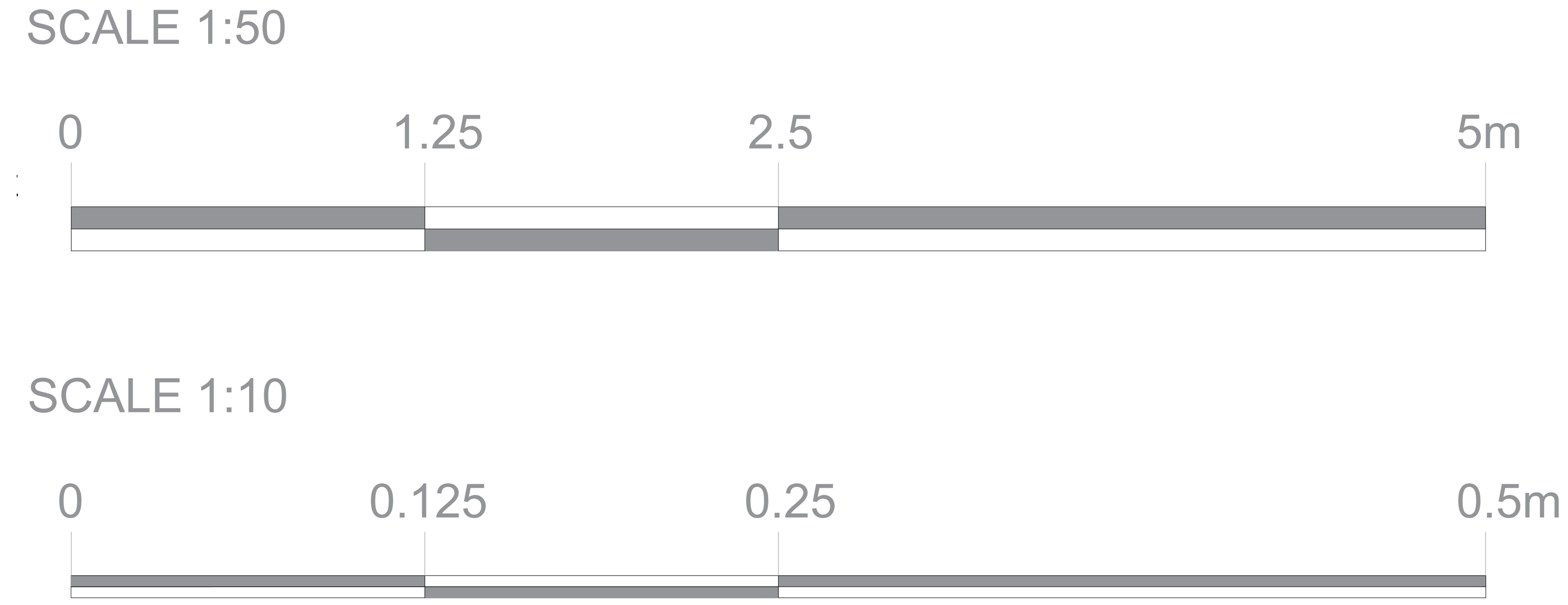


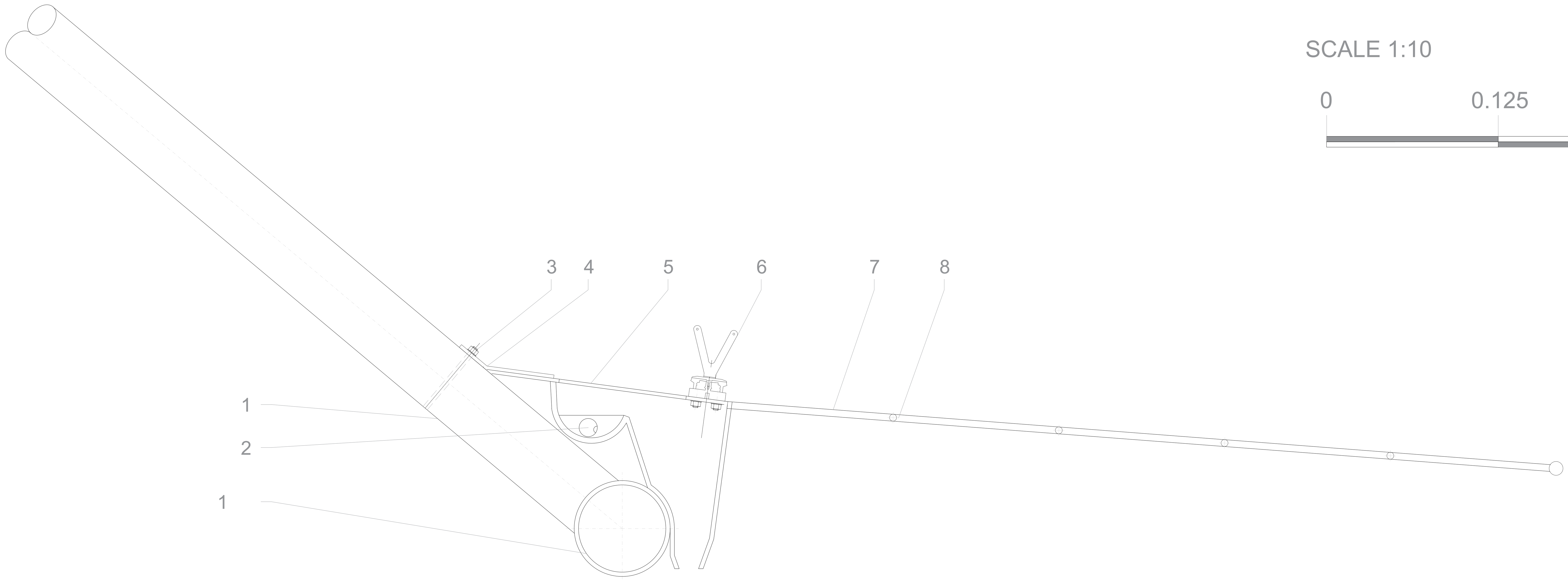
ELEVATION

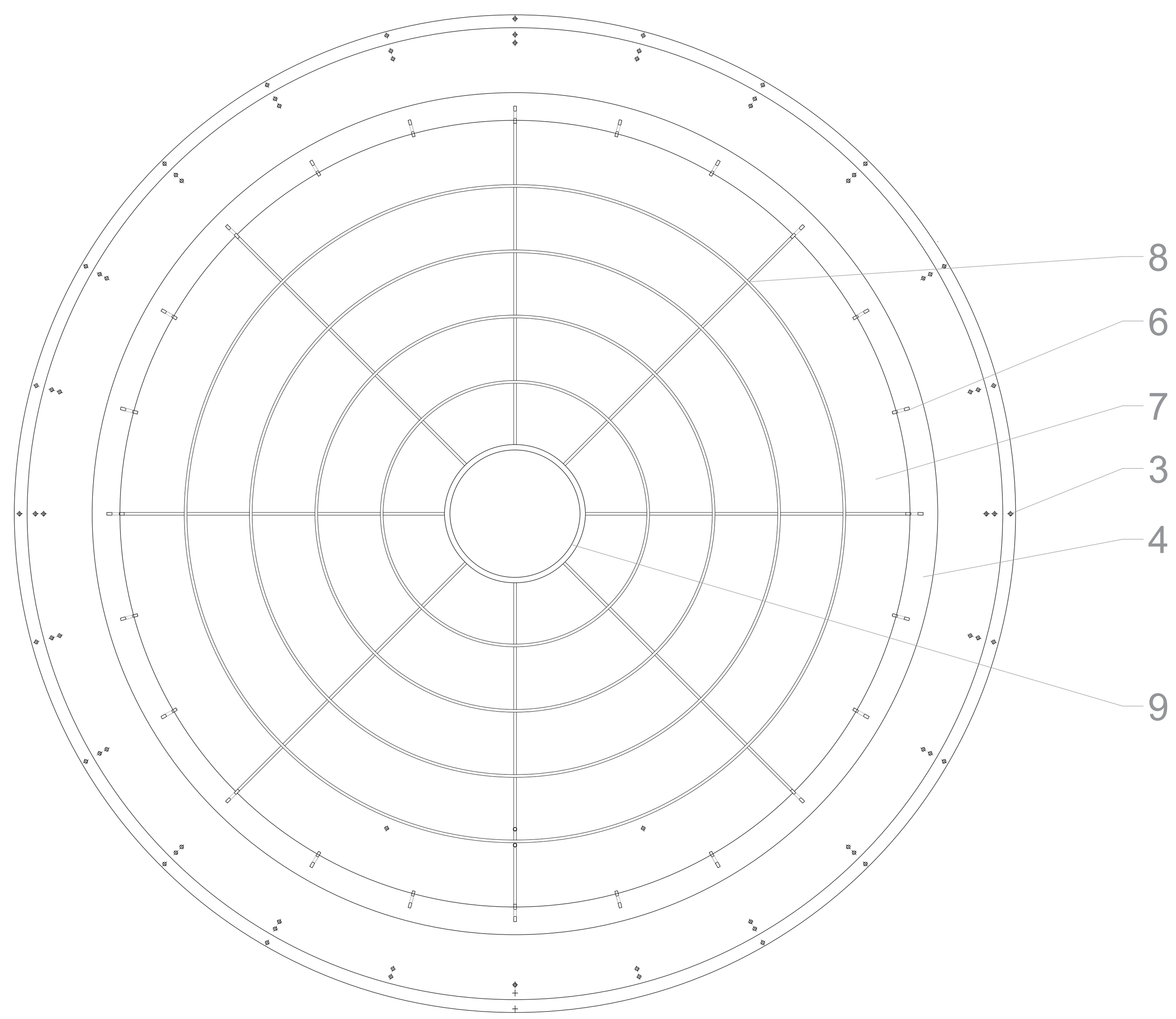
SCALE 1:50



GLASS DETAIL



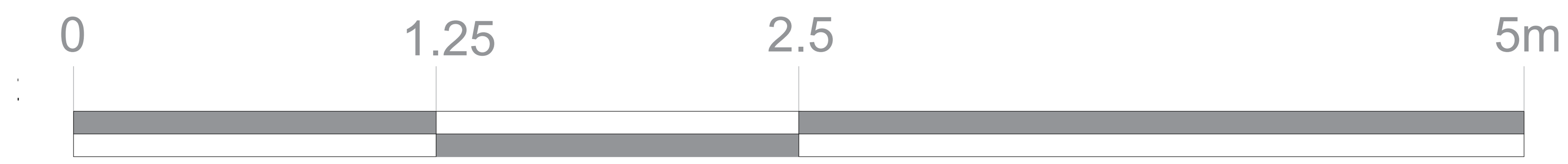


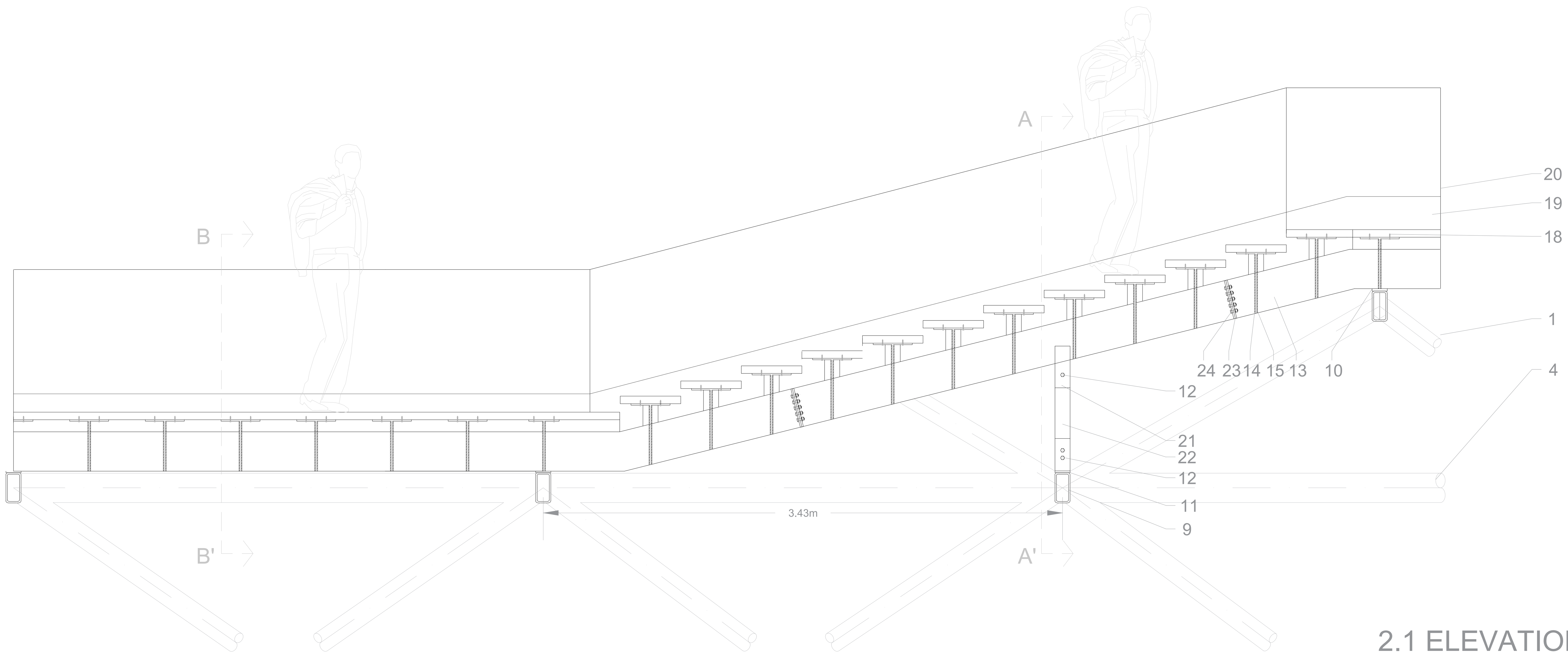


1. CHS 139.7x6.3 S355 SECTION WITH C5 ANTI-CORROSIVE COATING
2. WATER PIPE TO CREATE ARTIFICIAL WATERFALL EFFECT
3. BOLT
4. WELDED PLATE BETWEEN ALUMINIUM COVER PLATE AND BEAM
5. ALUMINIUM CVER PLATE WITH FUNNEL TO DIRECT WATER
6. BIRD PROTECTOR
7. PTFE ROOF
8. PURLINS TO SUPPORT PTFE
9. COMPRESSION BEAM TO KEEP PTFE TAUT
10. HOLE TO ALLOW WATER TO PASS THROUGH

CANTILEVER DETAIL

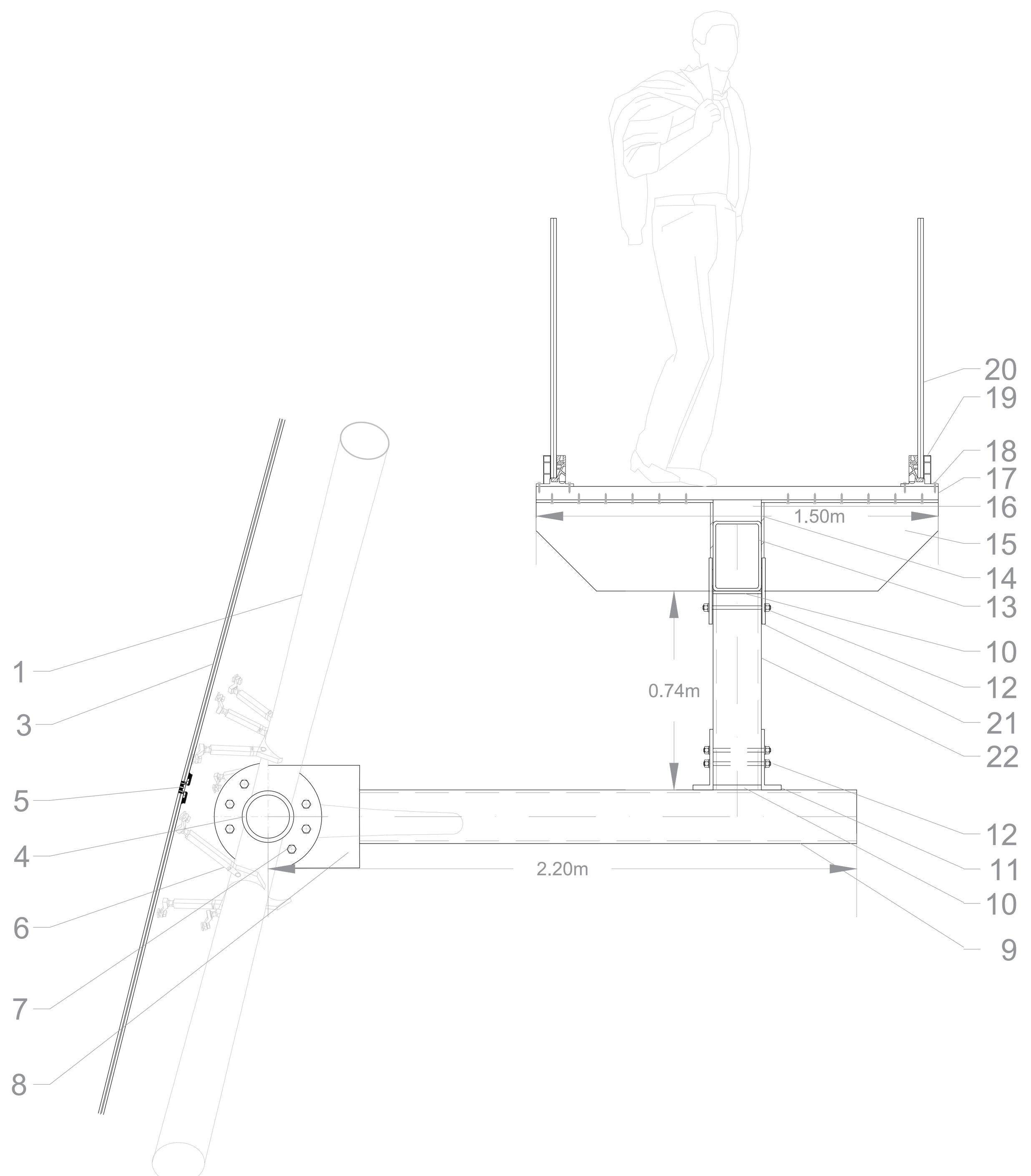
SCALE 1:50





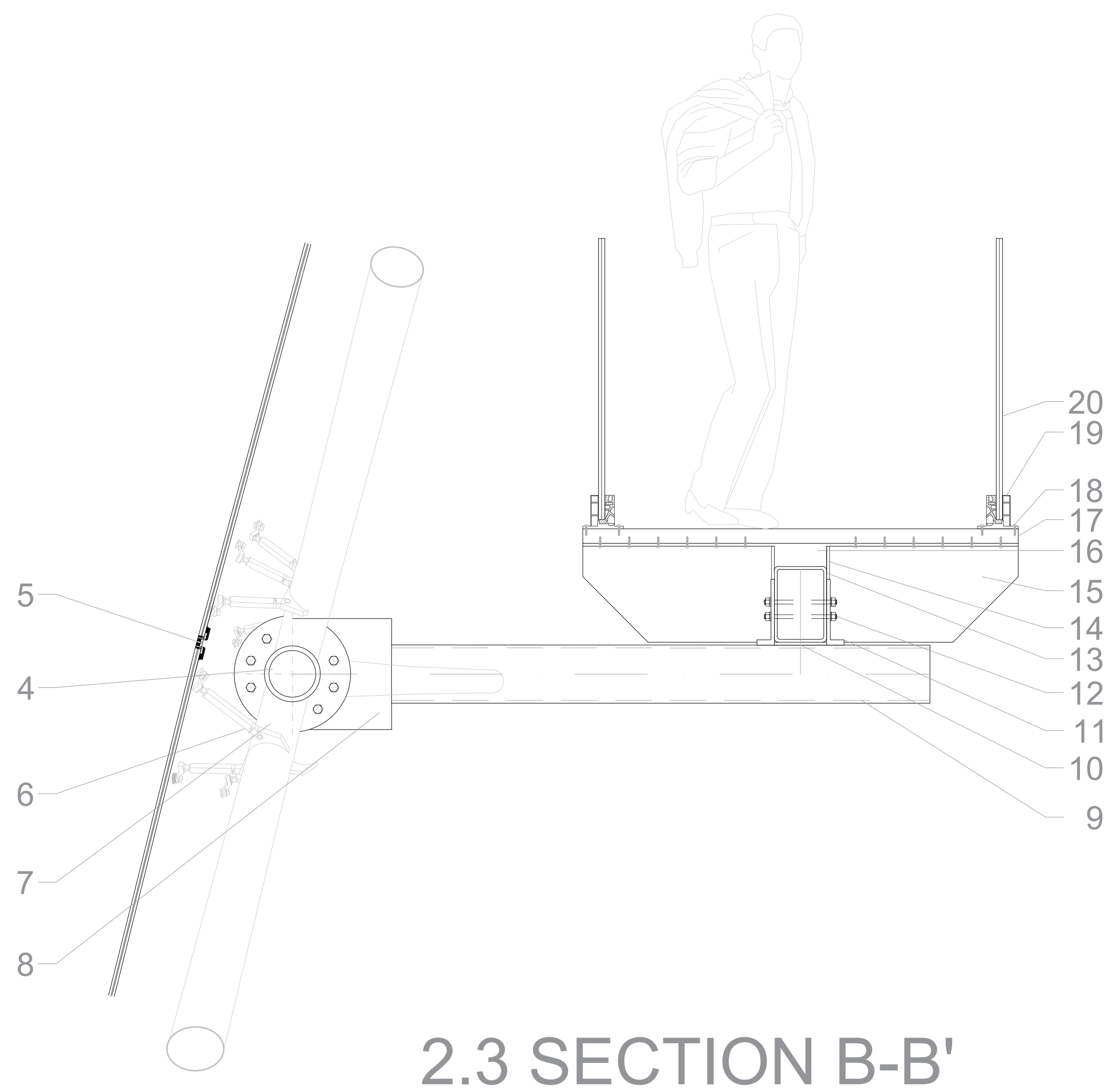
2.1 ELEVATION

SCALE 1:20



2.2 SECTION A-A'

SCALE 1:20



2.3 SECTION B-B'

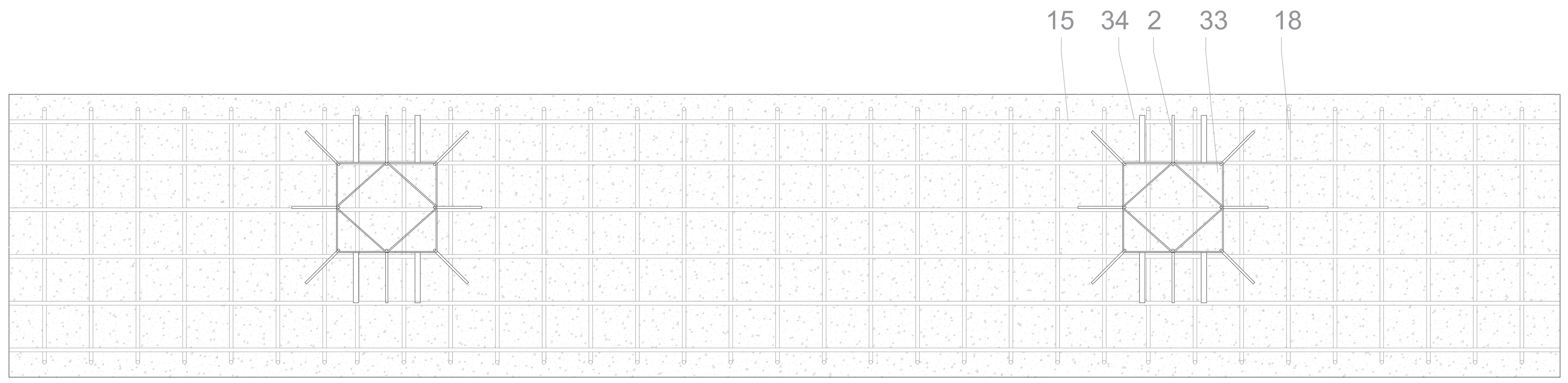
SCALE 1:50

1. CHS SECTION S355 139.7x6.3
2. CHS SPLICE
3. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
4. CHS SECTION S355 193.7x16
5. SILICON
6. NODE SPLICE DIAM. 400mm S355 STEEL PLATE
7. M20 G8.8 BOLT
8. CROCODILE NODE 30mm S355 PLATE-RHS CONNECTION
9. CANTILEVERED BEAM S355 RHS 200x100x10
10. SHIMS
11. S355 WEB CLEATS WELDED TO BEAM
12. 180mm M20 THROUGH BOLTS
13. S355 RHS 260x1806.3 STAIRCASE BEAM
14. 10mm WELD BETWEEN STIFFENER AND BEAM (DONE IN PREFABRICATION)
15. S455 10mm STIFFENER
16. STEEL S355 WELDED SPACER
17. 50mm TIMBER STAIRCASE
18. SCREWS
19. GUARD RAIL
20. GLASS RAILING
21. S355 WEB PLATE PRE WELDED TO RHS STAIRCASE BEAM FOR BEAM-COLUMN CONNECTION
22. S355 RHS COLUMN SECTION 180x100x12.5
23. 10mm PLATE FOR RHS BEAM SPLICE
24. M20 BOLT FOR BEAM STAICASE SPLICE

FOUNDATION DETAIL

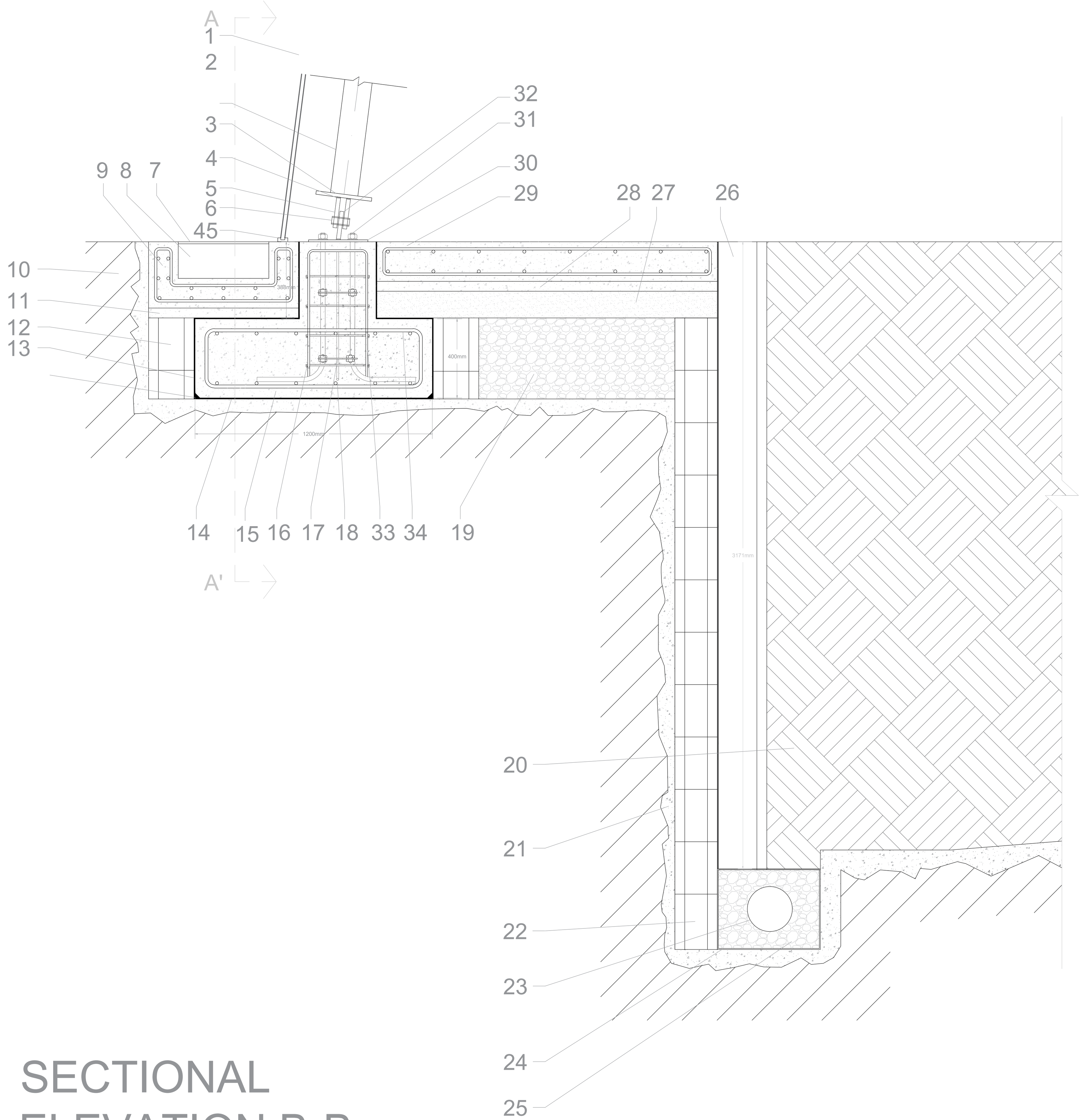
SCALE 1:50

0 1.25 2.5 5m



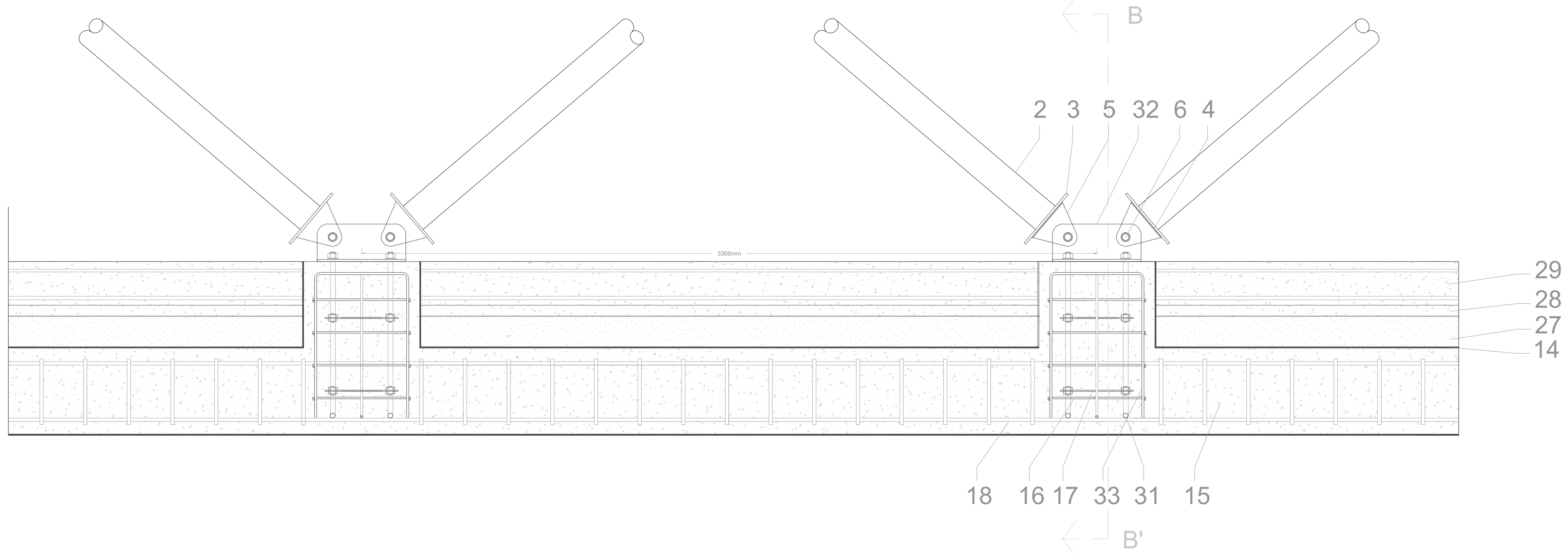
4.2 SECTIONAL PLAN

SCALE 1:50



SECTIONAL ELEVATION B-B

SCALE 1:50



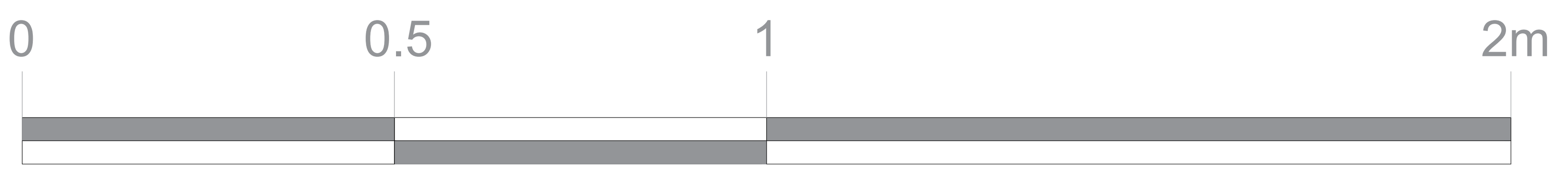
SECTIONAL ELEVATION A-A'

SCALE 1:50

1. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
2. CHS 139.7x6.3 S355 SECTION WITH C5 ANTI-CORROSIVE COATING
3. S355 300x285x17.5mm BASE PLATE
4. 5mm WELD
5. S355 165mm x 220mm x20mm PLATE
6. PIN CONNECTON 40mm DIAM
7. GRILL COVER FOR GUTTER
8. RAINWATER GUTTER
9. PRECAST GUTTER
10. GLOBIGERINA LIMESTONE
11. C15 CONCRETE BLINDING LAYER
12. 230MM HCB BLOCKS
13. SAND-CEMENT WEDGE
14. 5MM TORCH WELDED MEMBRANE
15. C40 CONCRETE STRIP FOOTING
16. T16 HORIZONTAL REINFORCEMENT @150mm SPACING
17. DIVISION PLATE
18. BOTTOM REINFORCEMENT T16 @200MM SPACING
19. GRAVEL FILL
20. ENGINEERING SOIL FOR TROPICAL PLANTS
21. C15 CONCRETE SIDE FILL
22. HCB 230MM CONCRETE BLOCK FOR SOIL-ROCK BARRIER
23. FRENCH DRAIN
24. GEOTEXTILE
25. GRAVEL FILL
26. PVC PIPE FOR RODDING PIPE ACCES
27. ENGINEERED FILL
28. C15 BLINDING LAYER
29. 200MM PRECAST SLAB
30. S355 FOUNDATION BASE PLATE
31. M20 J-BOLT
32. WELDED S355 CONNECTING BASE PLATE TO FOUNDATION
33. T16 TIES
34. TOP REINFORCMENT T16 @200mm SPACING
35. BARRIER FOR RESERVOIR
36. C20 200mm CONCRETE SLAB
37. BOND BEAM
38. CERAMIC TILING
39. WATER FROM WATER FEATURE
40. T16 REBAR REINFORCEMENT
41. T16 REBAR REINFORCEMENT LAPPED
42. 200mm GROUND SLAB
43. 200mm C30 IN-SITU SLAB
44. A503 MESH
45. RUBBER GLAZING GASKET

RESERVOIR DETAIL

SCALE 1:20



1. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
2. CHS 139.7x6.3 S355 SECTION WITH C5 ANTI-CORROSIVE COATING
3. S355 300x285x17.5mm BASE PLATE
4. 5mm WELD
5. S355 165mm x 220mm x20mm PLATE
6. PIN CONNECTON 40mm DIAM
7. GRILL COVER FOR GUTTER
8. RAINWATER GUTTER
9. PRECAST GUTTER
10. GLOBIGERINA LIMESTONE
11. C15 CONCRETE BLINDING LAYER
12. 230MM HCB BLOCKS
13. SAND-CEMENT WEDGE
14. 5MM TORCH WELDED MEMBRANE
15. C40 CONCRETE STRIP FOOTING
16. T16 HORIZONTAL REINFORCEMENT @150mm SPACING
17. DIVISION PLATE
18. BOTTOM REINFORCEMENT T16 @200MM SPACING
19. CONCRETE FILL
20. ENGINEERING SOIL FOR TROPICAL PLANTS
21. C15 CONCRETE SIDE FILL
22. HCB 230MM CONCRETE BLOCK FOR SOIL-ROCK BARRIER
23. FRENCH DRAIN
24. GEOTEXTILE
25. GRAVEL FILL
26. PVC PIPE FOR RODDING PIPE ACCES
27. ENGINEERED FILL
28. C15 BLINDING LAYER
29. 200MM PRECAST SLAB
30. S355 FOUNDATION BASE PLATE
31. M20 J-BOLT
32. WELDED S355 CONNECTING BASE PLATE TO FOUNDATION
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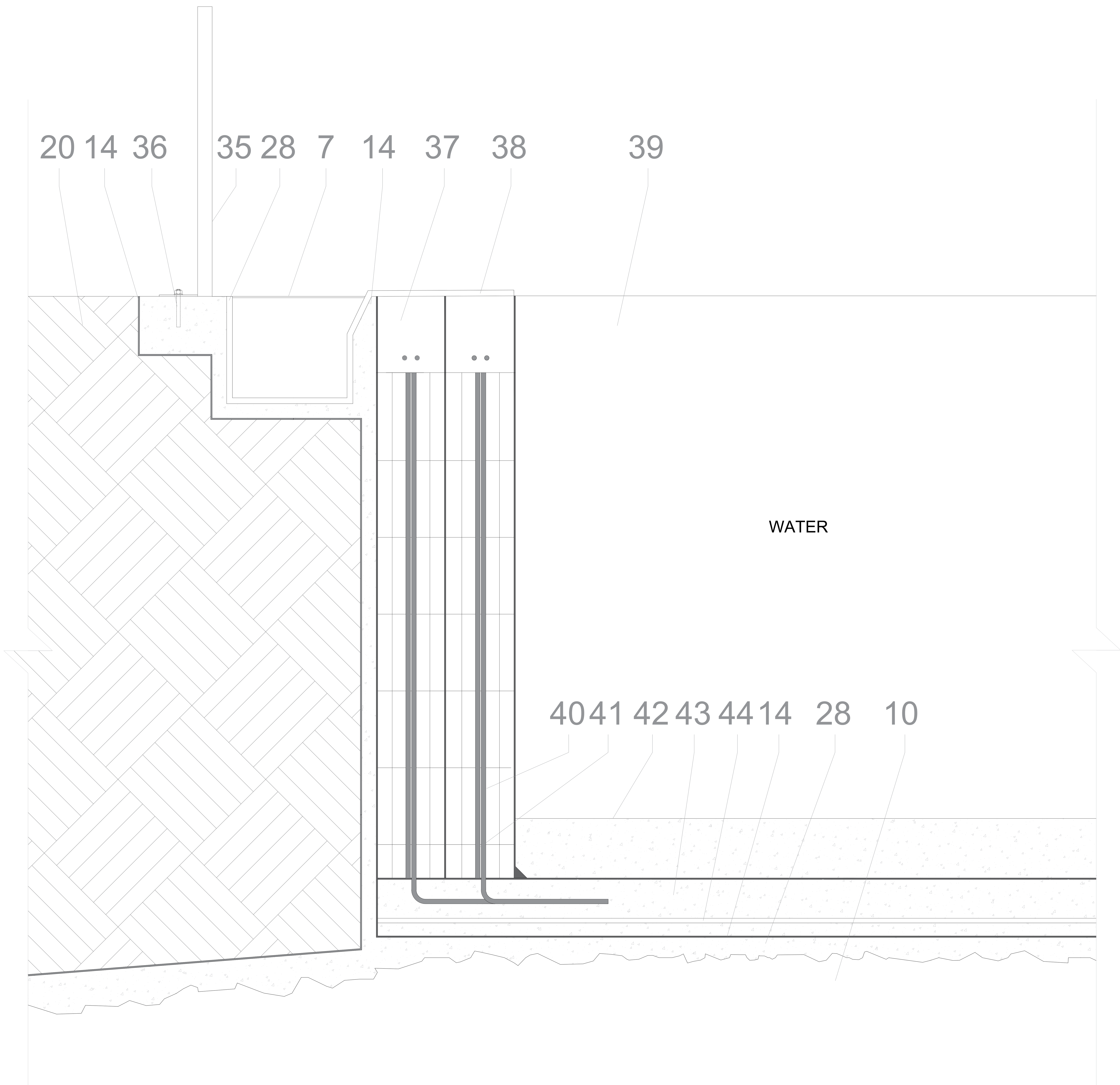


FOUNDATION AND GUTTER PLAN

SCALE 1:200

0 5 10 20m

Design Document

CVE5010-Thesis Project

Matthew Rapa

0228001L

Contents

Introduction

Locally, we lack several open spaces. This is common around all of Malta, especially in the Northern Harbour region which has become the economic hub of Malta. This has led to several development in the last 15 years. Within this northern harbour region, the concept of free, open green space has become very limited.

After an analysis of the whole region, the area of Manoel Island was further looked into. This is because the central location of the island provides a lot of opportunity. Historically, this was a strategic location for the British in the World War, developing the famous Fort Manoel. It was an area which had a lot of importance for the time. After the British left Malta, the importance of the island reduced tremendously year after year. So much so that its current state is that several old structures have been abandoned. The only restoration works which have been carried out are that of Fort Manoel. Several other buildings have been closed off due to being rendered unsafe structures. The perception of locals about Manoel Island is that it is currently unsafe to go, subject to a lot of crime and vandalism. This has been a result of many years of negligence to upkeep the area.

Locally, we fall victims of heavy developments whilst overlooking the benefits of the community. This very often benefits our economy but makes us lost our quality of life. A development in Manoel Island isnt one which should offer more of the same, but offer something different, a breath of fresh air for the Northern Harbour Region in Malta. Similarly in Malta, we could see the upkeeping of Ta Qali National Park, a zone which harmonizes our landscape within urban areas. This concept is something which should be replicated and improved on Manoel Island. This creates a zone enhancing both locals and tourists alike to go. The zone should also offer a possible area for the individuals working across Sliema Ferries and Gzira to access during, before or after their working hours of work as a break from the present urban landscape.

Masterplan Level

It is important to understand the project of Manoel Island from the entire Masterplan perspective.

The proposed solution keeps some aspects the same, as well as renovates some areas. It also creates a wide range of new activities.

- Upon entering one finds a large great lawn. This is the type of green area which is used to organize concerts and events and allow large volumes of people to enter. It will have several resting spaces for people to sit down and enjoy
- Workshop spaces are placed on the left side of the entrance of the island in exchange for what currently is an area for repairing boats. This will be a less busy area, more quiet than the great lawn. It aims to invite people to come sit down and enjoy their work break. It will be a calm area with art installations present.
- The dedicated space for fixing boats will still be there. However, this will be refurbished from its current state
- An area for wellness and sports will also be present in the middle. This aims to be a rehabilitation area for people to come and relax
- An area dedicated to camping will be found on one end. This will be structured and organized.
- Close to the lazaretto, an indoor garden will be present (main project)
- The lazaretto itself will be repurposed for museums, galleries and workshop spaces.
- Fort Manoel, MIDI building, chapel and promenade to be kept as is

Image: The drawn up masterplan

Erase-Rewind-Redux

One of the main principles developed overall with respect to this theme is to adjust our current mentality in terms of construction. Bad interventions are as bad as no interventions leaving many areas dilapidated. As stated, Manoel Island is in that current state because most people “fear” developing it because of how it may be perceived. The perception that a development needs to be something which prioritizes the pocket of the consumer is something which should be changed and is the way in which the “erase” is being tackled.

The rewind and redux theme are tackled in tangent with eachother with respect to Manoel Island. This is because if we had to go back in time (rewind), several old photos of Manoel Island show how the area itself was full of life and activity for the British during the Second World War. It was in fact the fulcrum of the Grand Harbour. The British even built several underground tunnels for submarines, and hidden oil tank reserves next to Fort Manoel. These remain present and havent been used since the second world war. They may be repurposed. This highlighted an area which was of a lot of importance towards the British empire in Malta.

The redux theme comes in here as this centre piece of Manoel Island would like to be recreated and brought back. It can very easily act as the breathing space within the North Harbour Region. No development is intended to be created on the area which will compete with Fort Manoel due to its historic significance. In fact, it will compliment the area, rather than compete with it.

Concept

Locally, we lack several green space, especially in the North Harbour region. Despite specifying a large green space as the main part of Manoel Island, something which will help to bring more people to the area would be to bring different types of plants. It is important to note that the type of plants and trees which grow locally are due to the temperature and environment which we have locally.

Creating an artificial controlled environment to vary the type of plants which grow inside it is something which will enhance people to visit the area. This is also going to be in a geographically very touristic location (as oppose to ta qali which has struggled from this). Moreover, the concept of creating a botanical garden is something which brings back the idea of the British, especially on Manoel Island. This is because botanical gardens in general are very common in other commonwealth countries. The British themselves are very well known for these gardens, even by naming the case studies of the Eden Project and Kew Gardens.

Image: Eden Project

Image: Kew Gardens

However, botanical gardens normally have very high internal heights. This enhanced the importance of looking further into the Eden Project as a case study. This is because, interestingly, this case study was built in a quarry, meaning from many different areas the structure itself isnt seen. This is important as from the Valletta side, looking across, a structure which competes with Fort Manoel isnt something desired. Therefore importance is given to where on Manoel Island is this garden going to be.

On the Ta xbiex side of Manoel island, close to the Lazaretto Building, there is a very large change in level. This site was chosen as the location for the project. The garden's structure can be nested into the excavated area. It is from the Ta xbiex side that Fort Manoel is seen least (as oppose to Sliema and Valletta). A proper thought out project can very easily be integrated in that particular area. Also, it enhances people to walk through the island to get to, rather than placing it at the entrance and disregard the rest of the island.

SDG Goals – From a masterplan and individual project perspective

SDG Goal 3 – Good Health and Wellbeing

The proposed masterplan plans to incorporate a community within Manoel Island. With projects such as activities and pedestrianising the whole area, a great flow of people will be present. This will increase human interaction.

SDG Goal 6 and 7- Clean Water and Affordable Clean Energy

The polluted marina will be regenerated. Recirculation of water will be present with the end result of water being for plant irrigation. The pedestrian areas will also be benefitting from cleaner air in the area through this system

SDG Goal 8 – Decent Work and Economic Growth

Currently, there is hardly an economy on Manoel Island. There is no life and the area is run down. Therefore the area can be redeveloped and appreciated. This will inherently bring more economic growth in the area with a market and demand for people to visit.

SDG Goal 9 and 11 – Innovation and Infrastructure, Sustainable cities and communities

The concept proposed at masterplan level is something new locally.

Understanding different climates and how gardens are designed for them

1. **Tropical Climate**

Architectural Features

- Transparent Materials (tempered glass, ETFE) so that heat is trapped
- Ventilation (High Humidity) and use of sprays and foggers
- Temperature Control (20-30 degrees) – double glazing or thermal insulation
- Diffused natural light using translucent materials
- A lot of water: ponds etc
- Durable materials such as stainless steel or treated wood

2. **Desert Climate**

Architectural Features

- Enclosure- low rise glasshouses. Transparent materials for maximum sunlight
- Ventilation – openable panels in hotter months, passive cooling systems
- Temperature control- insulation against too much heat
- Full exposure to direct sunlight with reflectors. No artificial light
- Rocky area and sands
- Drip systems for irrigation
- Steel

Comparison Table

Feature	**Tropical Rainforest Design**	**Desert/Arid Design**
Enclosure	Airtight to trap heat	Open-sided structures with focus on sunlight
Ventilation	Controlled airflow to retain moisture	Cross-ventilation
Temperature	Heating systems to keep warm temperature	Insulation and shading to moderate temperature
Lighting	Diffused light to simulate canopy filtering such as shading	Direct Sunlight
Water Systems	Water features for high humidity in the air	Minimal use of water
Plant Layout	Dense and large amount of plants	Spaced out plants

6 types of plants used in Tropical Indoor Conditions

- Bird of Paradise (*Strelitzia reginae*)

- Monstera (*Monstera deliciosa)*

- Areca Palm (*Dypsis lutescens*)

- Calathea

- Philodendron (*Philodendron hederaceum* or *Philodendron selloum*)

- Peace Lily (*Spathiphyllum spp.*)

- Bromeliads (*Bromeliaceae family, e.g., Guzmania or Neoregelia)*

- Alocasia amazonica (Amazonian Elephant Ear)

- Bird’s Nest Fern (Asplenium nidus)

- Anthurium andraeanum (Flamingo Flower)

- Stromanthe sanguinea (Triostar)

- Ctenanthe burle-marxii (Fishbone Prayer Plant)

- Ficus elastica ‘Tineke’ (Variegated Rubber Plant)

- Myrtus communis (Common Myrtle)

- Styrax Officinalis (Snowbell Tree)

- Chamaerops humilis (Mediterranean Fan Palm)

- Acer Monspessulanum (Montpellier Maple)


- Viburnus Tinus (Laurustinus)

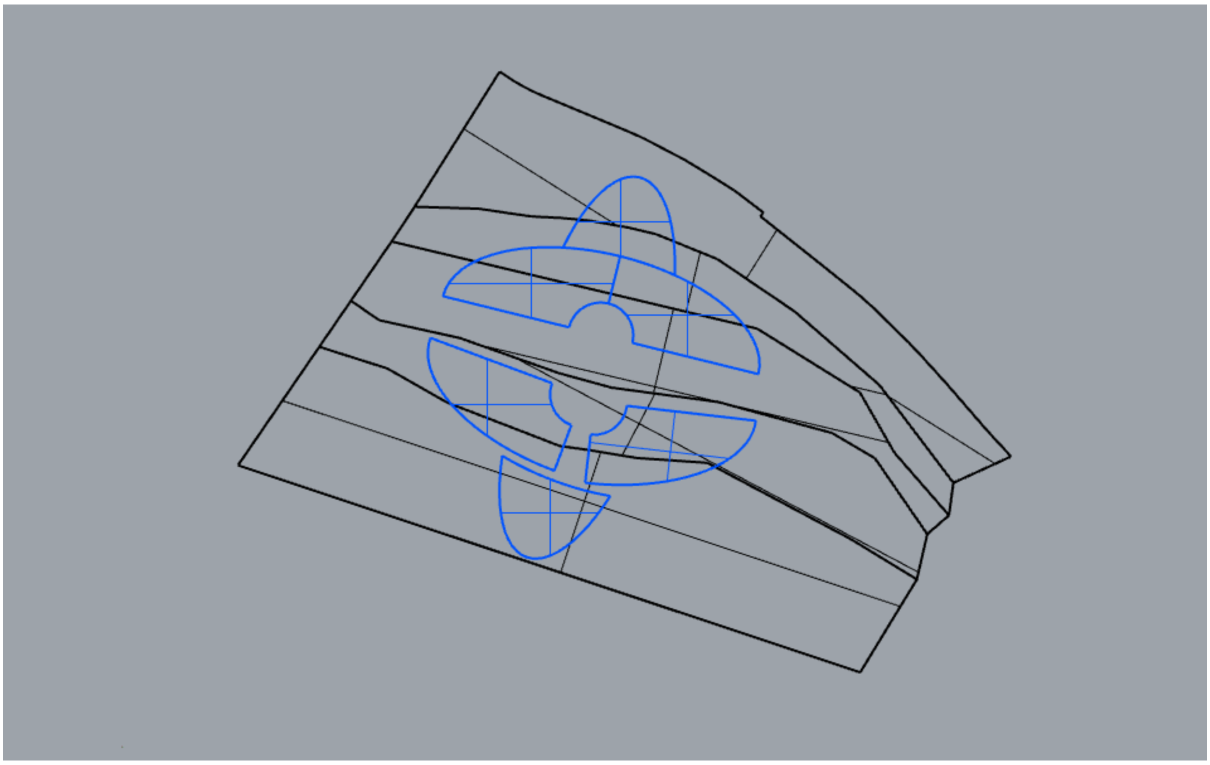
- Cercis Siliquastrum (Judas Tree)

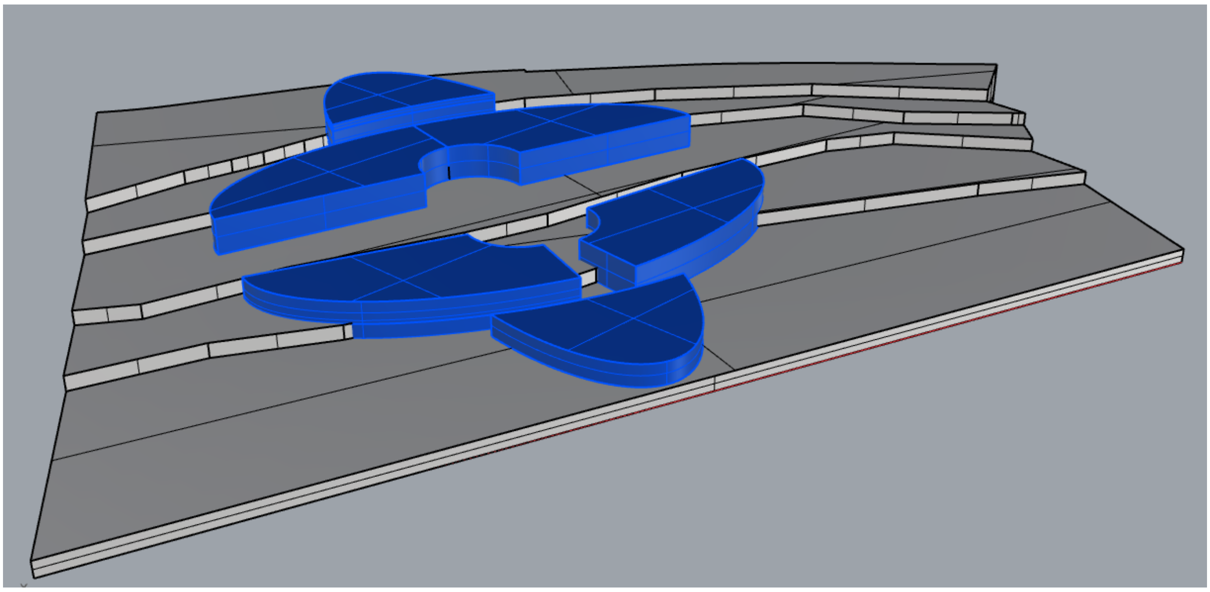
(Hessayon, 1993)

(Barwick, 2004)

Massing Development

Stage 1:

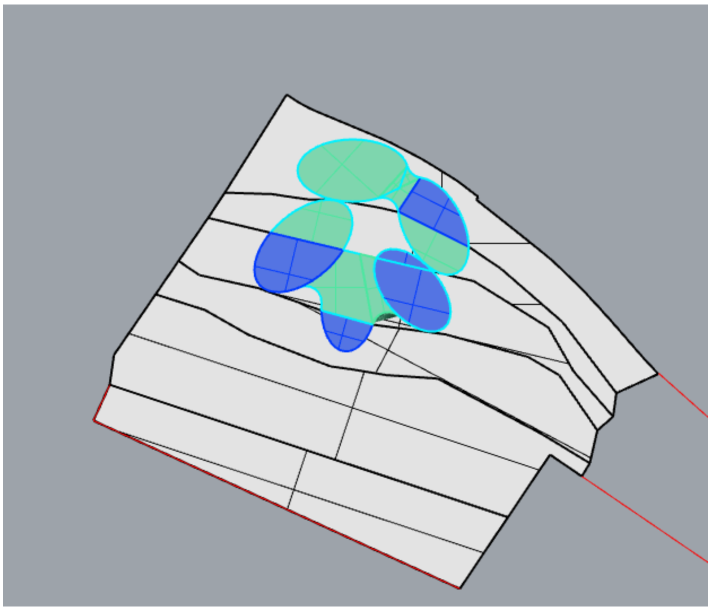


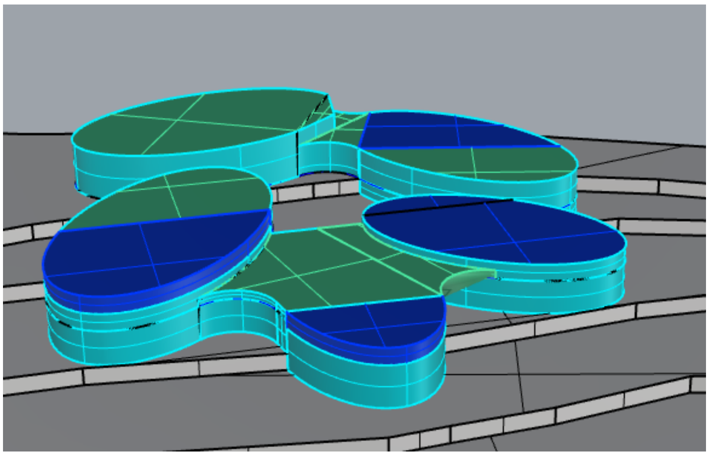


The massing is carried out on 2m contour intervals so that different heights can be explored. A non-intrusive structure can therefore be carried out in a sensitive location which doesn’t compete with Fort Manoel. The shape is organic and abstract. The abstract look is resembling that of a flower with petals.

However, the massing is developed further because the structure looks too divided in the middle.

Stage 2:



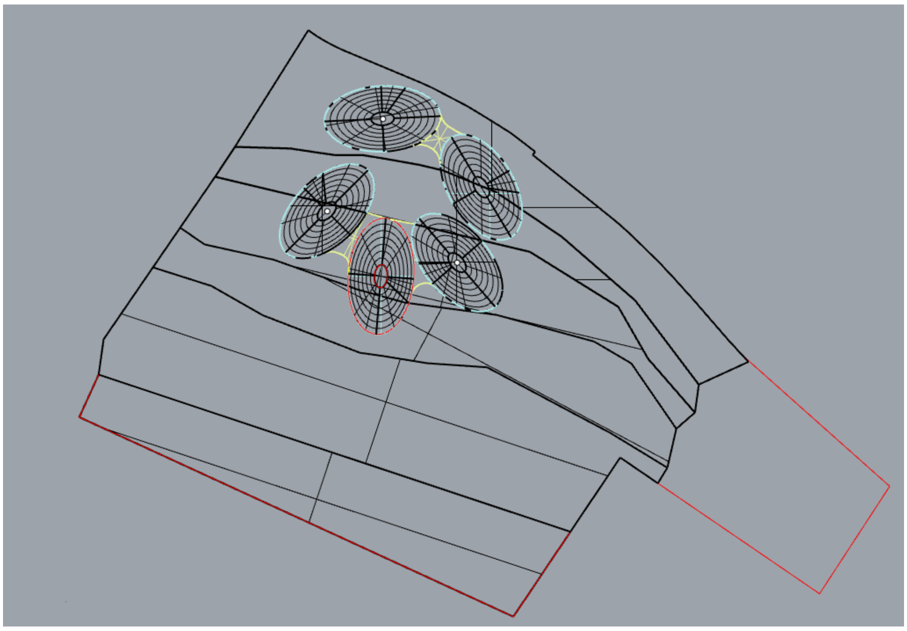


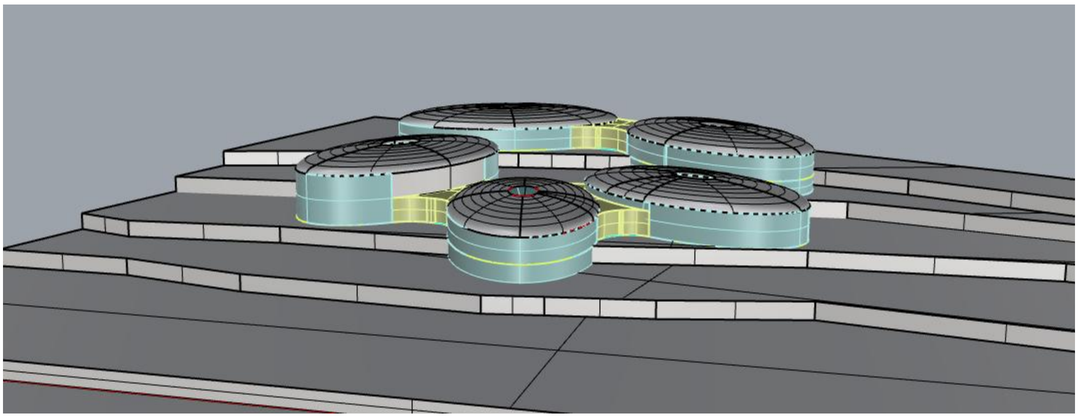
In order to treat the abstract idea of having a flower or petals, 5 separate structures adjacent and under eachother were created on separate levels. The idea of having different level was still respected through this approach.

The skeleton of these 5 structures is the same. This is important because of the modularity which comes with it, making project management of this design much simpler. The idea is that these 5 structures will house 5 different micro-climates. The different micro-climates will allow different types of plants to grow inside because of the controlled environments.

The 5 separate structures are connected through these intermediary zones, acting as buffers within the controlled environment zones.

Stage 3:

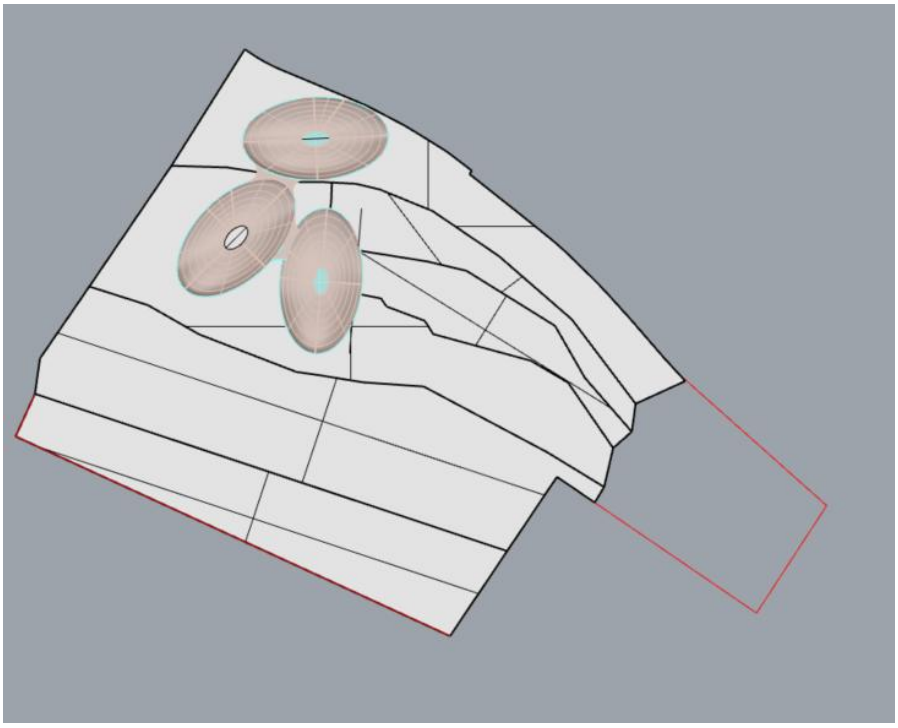


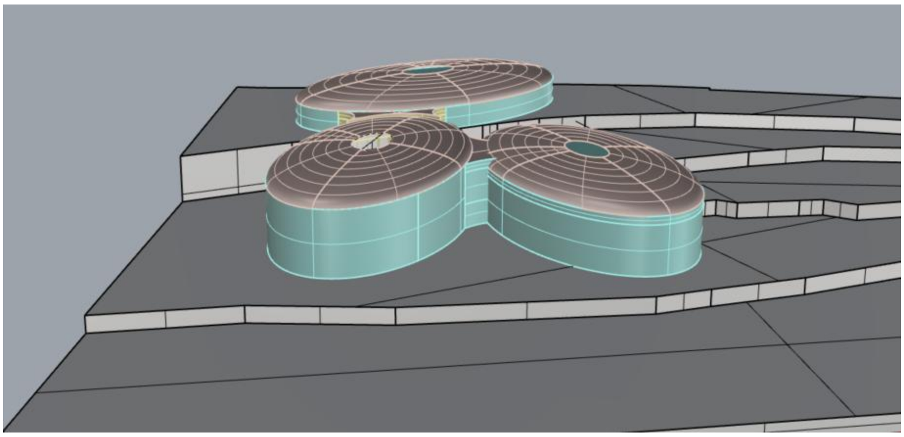


The previous concept of stage 2 is developed further. The heights are once again given a lot of important so that the south facing areas can have a maximum internal height of approximately 10m.

The roof is now curved to given it more of that curved shape which was desired.

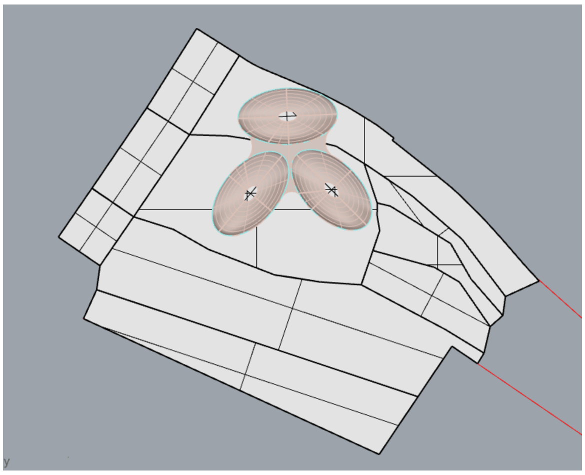
Stage 4:

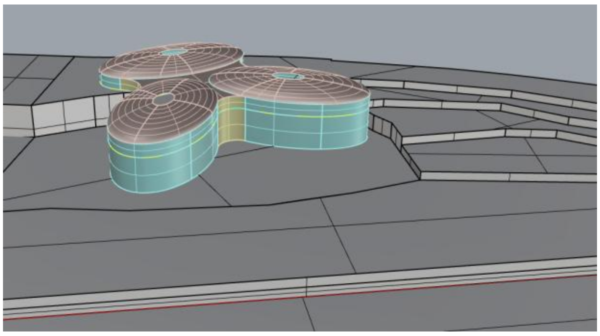




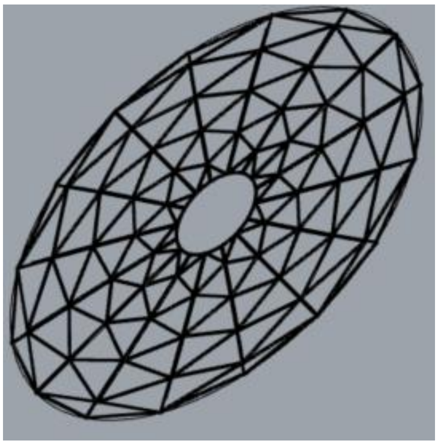
Further development has resulted in changing from 5 separate structure to 3 seperate structures, still keeping the intermediate zone in between. In this case height is given more of a priority, with maximum heights of 13m in the bottom south facing areas. This is because creating such a structure whilst limiting its height will limit the type of trees and plants inside. Therefore, a way to create a structure which allows for a large height to be present, whilst also not being imposing is a very important hurdle to tackle.

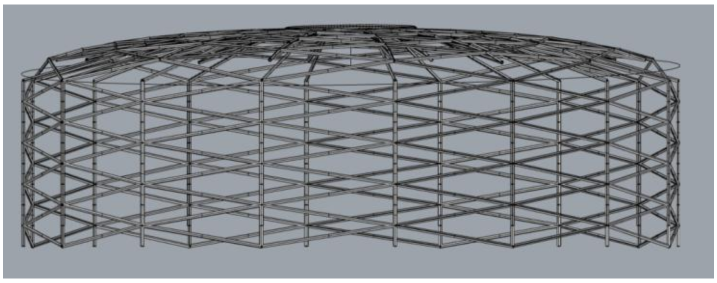
Stage 5:





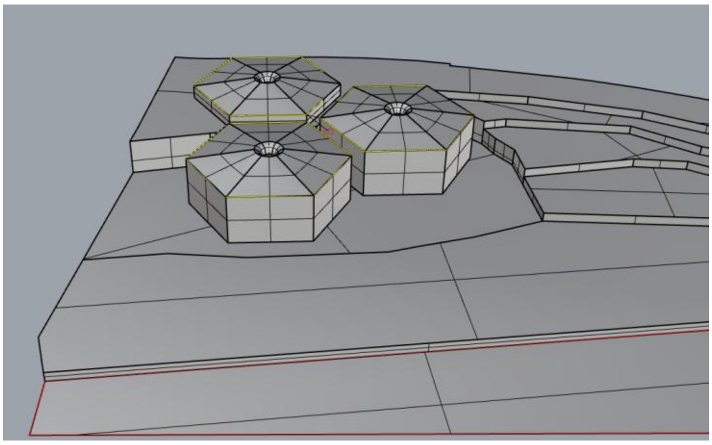
The orientation of the structure is changed so that the amount of sunlight which is received by the structure is maximised. Since the structure is south facing, it will make sense to have a very large horizontal distance.

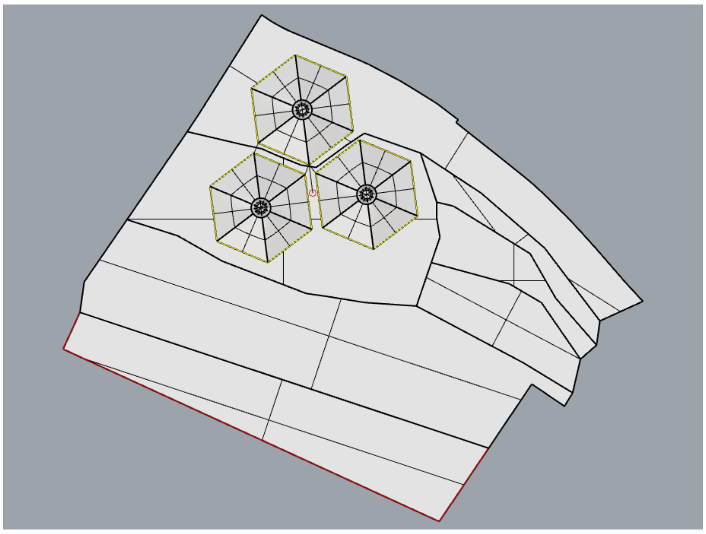




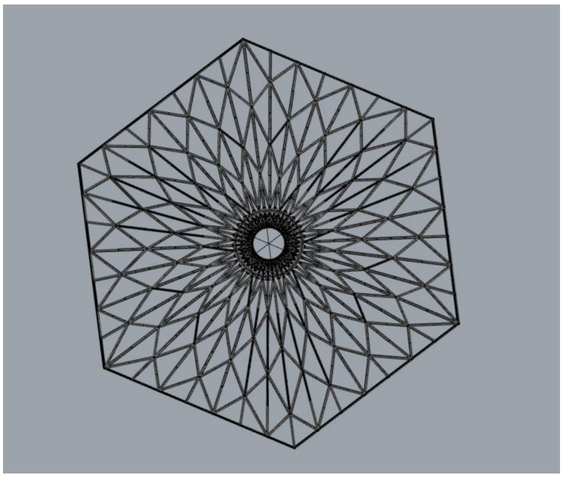
A skeleton of the massing started to be understood. This is so that a better understanding of connections can be carried out. With an ellipse being quarterly symmetrical, it will not be efficient to have this type of skeleton. The angles between the connections change at every interval too, meaning that this skeleton is a very laborious and complicated system. From now on, more symmetrical shapes started to be followed.

Stage 6:

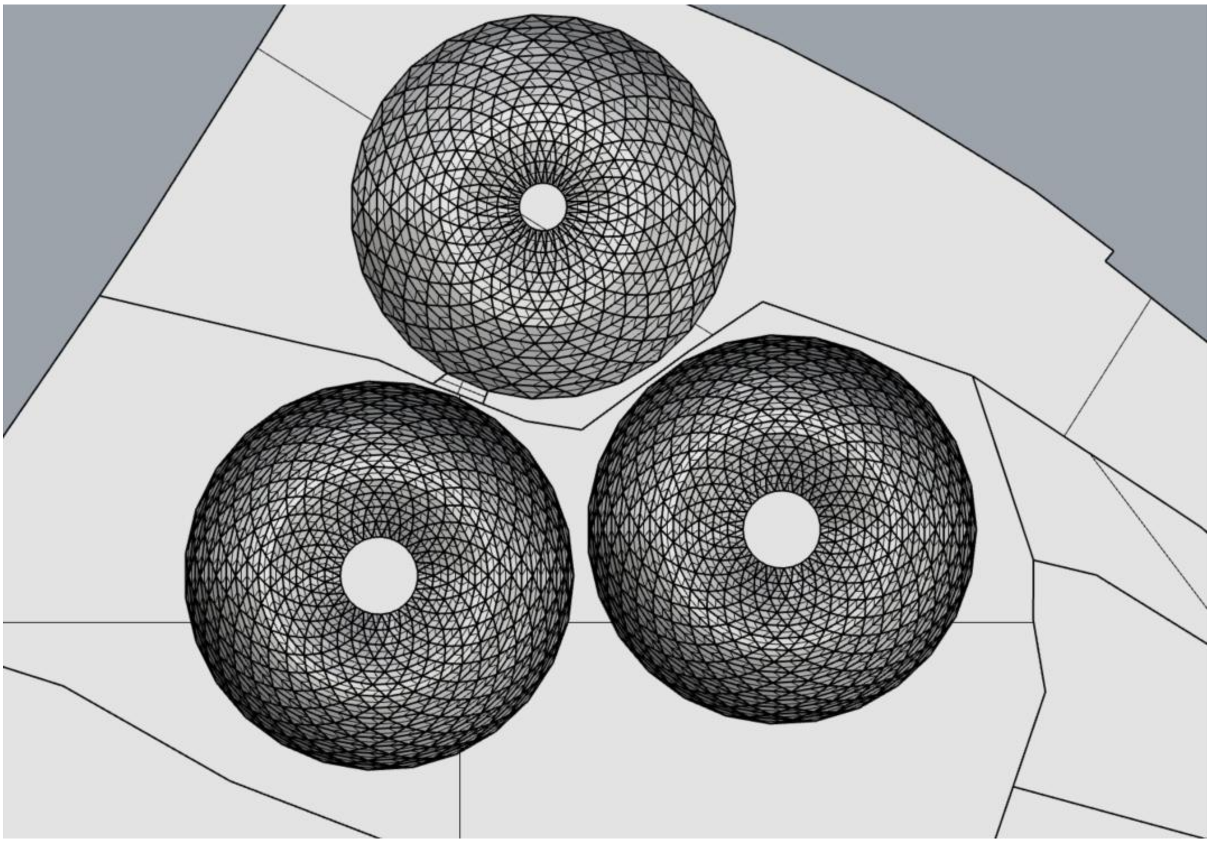


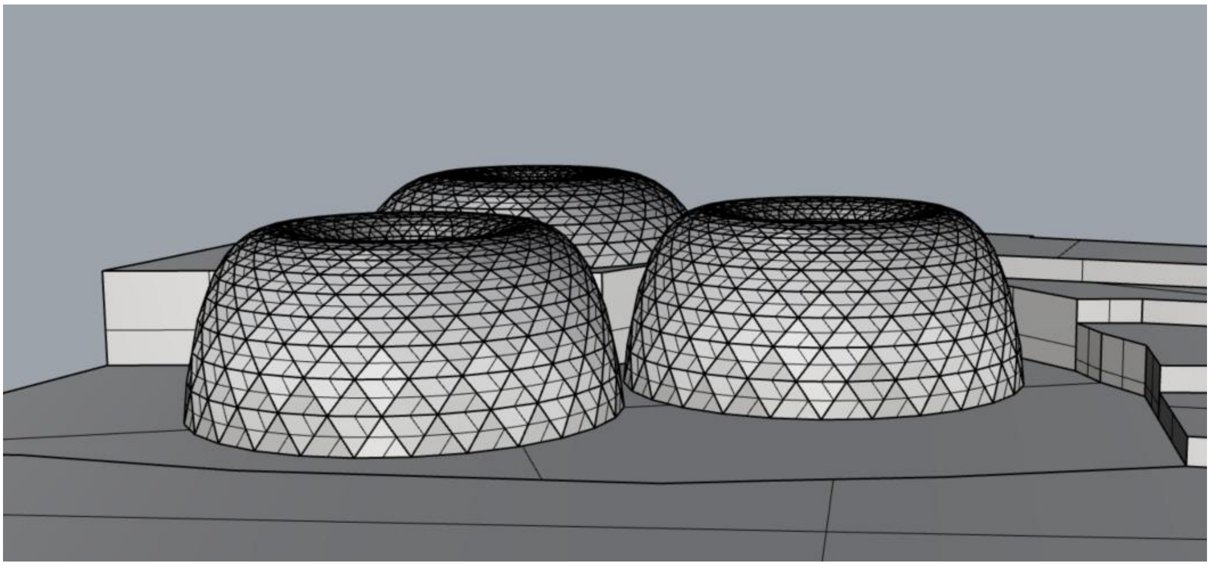


A more symmetrical approach started to be followed for the massing. This will aid the connections and modularity of the project.



From a skeleton point of view, despite the shape being more symmetrical, the angles converging to the centre are still changing at every interval. This is something which should be avoided as much as possible.





The massing is further developed so that an organic shape is kept, maximising modularity in connections by keeping the converging angles between the connections the same, and maximising the symmetry as much as possible.

The structure is still once again closed off to have a controlled environment. However, a water feature is now found in the middle. This is created as the roof now curves downwards forming the new middle structure which can be seen in the section below:

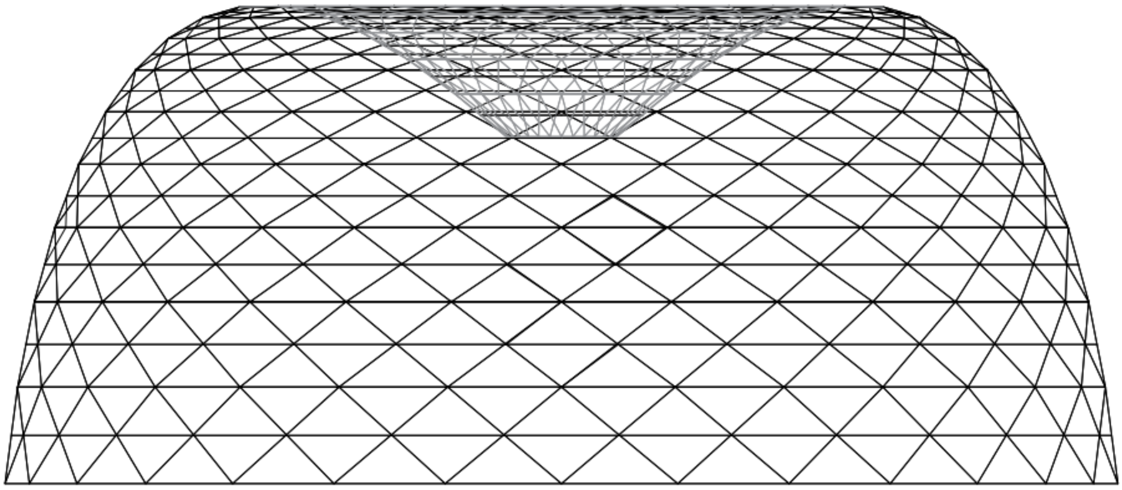


Image: A photo of a section of the curvilinear roof

Justifying the complex shape

It is important to appreciate that a shape like the one specified above costs a substantial amount of money. Therefor the installation of a conical feature should be justified.

Reasons for the shape include:

- Center-piece of the garden, being an architectural phenomenon making it a must-visit attraction
    - This will boost local and foreign visitors providing a better return on investment and overall experience
    - Increases the local foreigners by offering an artificial feature of a waterfall. Locally we lack several water features and this provides a feature of something which our size, climate and geography cant
- Functional design
    - The conical waterfall acts as a natural climate regulator cooling the surrounding areas
    - Humidity generator which is ideal for microclimate
    - Increases the catchment area of rainfall which is then directed to the man reservoir

Design of Centerpiece

The centre of the conical flask is circular. This is always partially open. Even though this does actually allow for natural ventilation to occur. The size and shape of this opening should be engineered.

In reality, the main function of this opening is to allow for rainfall to pass through. Without the presence of this opening, rainwater will gather on the roof and will not be dissipated in any way.

The rainwater is always going to be directed to its centre through its shape. This water will fall into the swamp environment which is going to be calculated. This water is then slowly circulated to the main reservoir. The water in this reservoir is either used to recirculate back to the waterfall feature or for the general irrigation of the garden. It can also be used for the building utilities such as the bathroom.

Understanding the flow of the water feature

The water feature in the middle, requires careful thought. This is because a desired flow will need to be chosen. Several water fountains in general change their flow of water when a water show is going on. For example, the Singapore Jewel Changi Airport changes its flow of water from 4.5 m3/ minute to 23 m3/minute for 20 mins every hour. This provides a spectacle for the people to gather around the fountain for those set minutes. The actual flow of water is not a standard flow, however it is dependent on the size of the perimeter of the circle. *(https://www.cibsejournal.com/technical/modelling-the-worlds-highest-indoor-waterfall-at-jewel-changi-airport/, 2021)*

Image: A photo of the regular flow of water at the Singapore Airport

The amount of water needed is dependent on this flow. Apart from this, it is important to understand the recirculation time of the water. This is because even though you can easily calculate the amount of water which is falling down a particular height with respect to the flow, you also have to take into account the recirculation time of the water. This is obviously very much dependent on the efficiency of the system to pump the water back to the top. In theory, this can be very quick. However, for the concept of botanical, a very quick system may not be as sustainable. Apart from this, the feel of water slowly being pumped may give a more relaxing and aesthetic feel. Quicker systems also result in more splashing and water loss. Slower systems allow for better filtration to take place as well.

Roofing materials

The panels of the roof were either going to be installed out of Glass or out of Polycarbonate. These both had their own advantages and disadvantages with respect to the Maltese Mediterranean climate.

Advantages For glass:

Aspect	**Tropical Botanical Garden**	**Continental Botanical Garden**
Maximising Natural Light	Lot of sunlight for tropical plant growth	Supports sun-loving plants
Heat Retention	Maintains warm internal temperatures for tropical plants	Captures day heat and reduces night drop in temperature
Humidity Cooling	Traps moisture for high humidity and tropical vegetation	Helps ensure moderate moisture, minimizing dehydration
Rain and Weather Protection	Prevents excessive cooling or rain	Shields plant from Mediterranean rain and wind
Aesthetic	Tropical environment experience	Suitable all year round
Water Use efficiency	Can have integrated systems for rainwater collection	Optimize water collection and conservation for dry summers

Disadvantages for glass:

Aspect	**Tropical Botanical Garden**	**Continental Botanical Garden**
Heat Accumulation	May overheat without ventilation	Overheating in summer needing cooling systems
High Maintenance	Cleaning for light transmission and minimizing algae	Upkeeping for maximum sunlight and climate control
Structural Limitations	Robust framing in high humid conditions	Must withstand the mediterranean winds and storms
Glare	Excessive sunlight damages plants	Can destroy internal environment
Initial Cost	Expensive initial investment	Expensive initial investment
Energy use	Supplemental cooling or dehumidification required in summer	Increased energy demand for cooling in hot Mediterranean Summers

Advantages For polycarbonate:

Aspect	Tropical Botanical Garden	Continental Botanical Garden
Maximising Natural Light	Diffuses sunlight whilst reducing glare	Provides uniform lighting for plants
Heat Retention	Maintains warm internal temperatures for tropical plants	Retains heat during cooler nights extending growing seasons
UV Protection	Protects Plants from excessive radiation	Reduces leaf damage in such plants
Impact Resistant	Shields plant from Mediterranean rain and wind	Shields plant from Mediterranean rain and wind
Lightweight structure	Reduces structural load enabling larger spans	Reduces structural load enabling larger spans
Cost efficiency	Lower material and installation costs especially compared to glass	Lower material and installation costs especially compared to glass

Disadvantages for polycarbonate:

Aspect	Tropical Botanical Garden	Continental Botanical Garden
Heat Accumulation	Will need ventilation	Overheating in summer needing cooling systems
Light Diffusion Limitations	More direct sunlight for certain plants will be needed	More of these plants will require direct sunlight
Yellowing over time	Panels will discolour reducing light transmission	Panels will discolour reducing light transmission
Scratching and Abrasion	Scratching reduces light transmission over time	Scratching reduces light transmission over time
Maintenance Challenge	Frequent cleaning to prevent algae	Needs regular recoating to retain functionality
Energy use for climate control	Additional cooling need to manage heat rapped during summers	Ventilation and cooling systems required to regulate internal temperature

Structural Material

Steel and Timber were the 2 materials which were compared to make up the gridshell roof. Both material have several advantages and disadvantages and a table was drawn up to gain a better understanding of which material to choose and why.

Advantages:

	Timber Gridshell	**Steel Gridshell**
Aesthetic	Compliments botanical settings	Modern look
Sustainability	Renewable and eco-friendly	High recyclability with potential reuse in construction
Structural Strength	Strong and lightweight	Can support larger spans
Thermal Performance	Offers better insulation	Conducts heat
Adaptability	Highly flexible	Can handle more complex and heavy-duty loads
Carbon Footprint	Low	Can be low
Maintenance	Maintenance needed depending on climate and location	Very durable

Disadvantages:

	Timber Gridshell	**Steel Gridshell**
Longevity	More susceptible to rot and moisture	Can rust
Fire resistance	Coatings needed	Not flammable
Load Bearing Capacity	Less than Steel	High loads with thin members
Cost	Initial cost cheaper but ongoing treatment	Higher initial cost
Environmental sustainability	Exposure to high humidity is problematic	Resistant to humidity
Construction	Skilled workers	Can be Prefabricated

Final Material Design

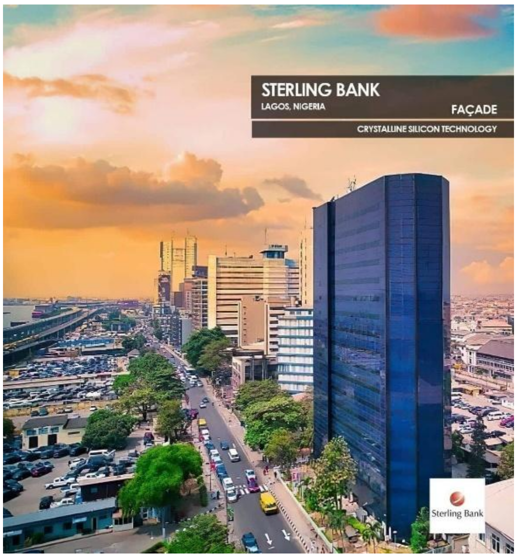
After careful consideration, the chosen materials were glass for the roofing and steel for the structural material.

One of the many reasons why the gridshell was designed out of steel not timber was due to the unforgiving precision in humid environments and the size of the sections. However, regarding the staircase and the passageway, it was decided to have these made out of timber. This is primarily because the section sizes being larger wont be an issue (as previously this would take up the space of the glass). Moreover, it is overall less critical when comparing the chain effect of a timber gridshell to a single element of a pedestrian bridge or staircase. The organic feeling of walking on a timber structure surrounded by timber elements will harmonize the nature feel. C5 coatings are used for the steel elements within the structure as these protect the steel from the humid environment.

(https://www.metallisation.com/applications/corrosion-protection-coating-life/, 2025)

Glass was chosen because the noise on the polycarbonate panels was a feature which couldn’t be avoided. Also, the aesthetic element of glass is a feature that will enhance the experience.

The type of glass used was Onyx glass. This type of glass has several advantages. This includes reduced glare and being a good resistance for moisture (needed in the high humidity environment). More importantly, the glass is coated with pv coatings on the panels and also can have additional e-glass coatings to reduce solar gain. This will overall generate a form of electricity which will help the project be more sustainable.



Images: Photos of Onyx glass used across the world

(https://onyxsolar.com/, 2025)

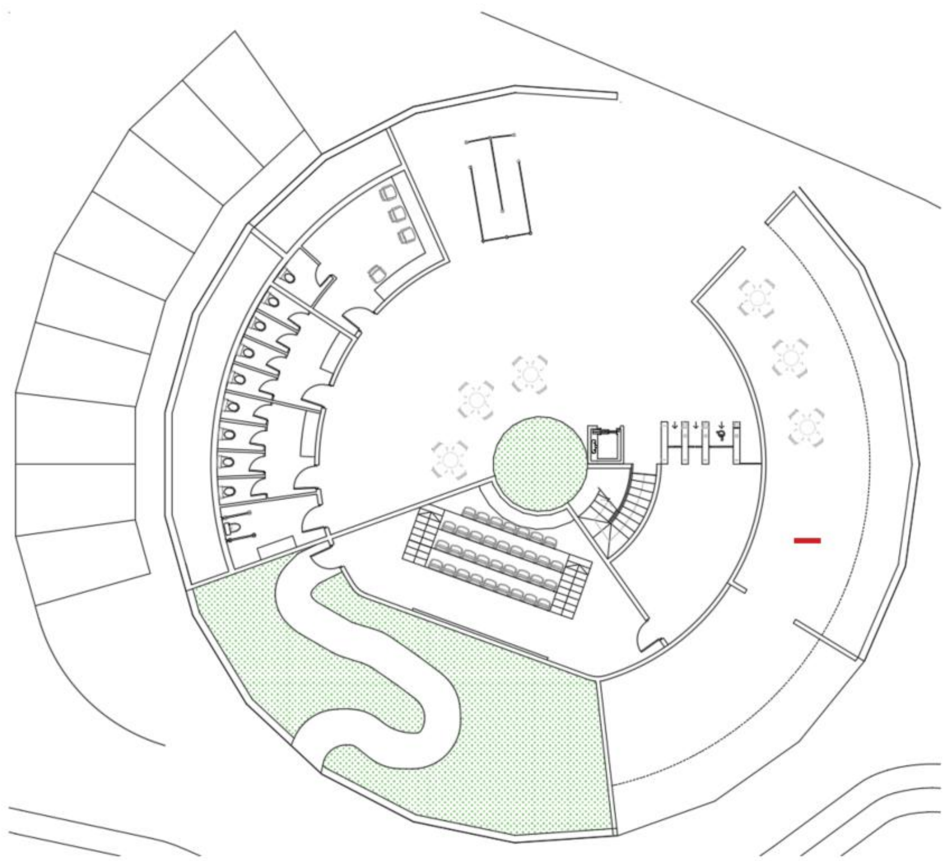
Indoor experience – Footpath

As mentioned earlier, the experience is split up into 3 different structures, connected to eachother. All 3 of them have several differences.

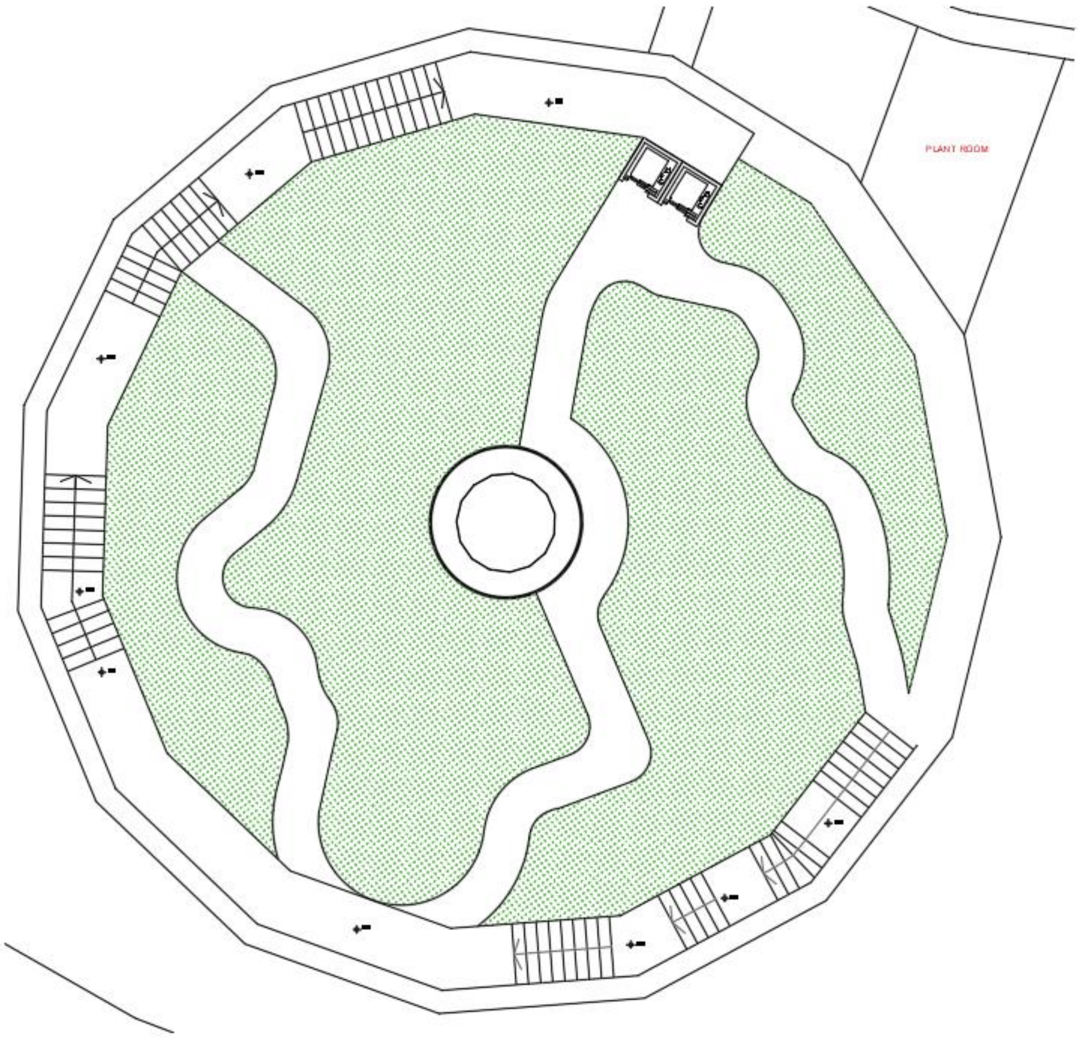
The top structure is the most different from the other 2. This is because it serves as the entrance for the whole experience. Right when you enter the building, on your right you find an area where you can purchase tickets in an ordered manner. Apart from this, one can find amenities such as the bathroom, coffee shop, and gift shop. Since this is the entrance, it can be found adjacent to the parking space and drop- off zone.

Ideally, the whole masterplan idea is to pedestrian-prioritize the whole area of Manoel Island. However, staff may still have access to the zone. Also, the area has a drop-off zone for the elderly and access-for-all people.

The first feature of the garden is an audio-visual zone. This is a very common feature in many botanical gardens which gives an insight to the garden prior to entering. Over here, several events and important days relating to the project can be explained to the visitors. Above all, it will showcase what type of plants are present and how the overall project contributes to the area. After this the pathway from the audio-visual area lead to the a small garden, giving a glimpse to the visitors, before crossing a pedestrian bridge to the top of the second structure, the main tropical botanical garden.



The way the footpath is designed, is that you first go down a flight of stairs around the perimeter of the building. In the case that the stairs aren't desired, lifts are also present to go down which fits the access for all requirements of buildings. The stairs are primarily designed so that you can originally feel close to the lush trees which grow up to 12m into the air. As you go down the stairs, you are automatically reminded of nature's large capabilities as you circle the vegetation. Importantly, the stairs are cantilevered from the structure. This was done like this both as an aesthetic feature and for the viewer to feel as though he is floating down the garden. From a foundation point of view, this aided the design as columns which were originally designed to support the staircase would need a foundation. This was going to be placed in the soil which was going to drastically influence the area of soil within the area. The footpath is also designed such that the internal space will be very close to the outdoor exits in case of fires.



Halfway down the stairs, a cantilevered passageway is designed crossing to the other side. This is designed for 2 main reasons. The first reason is for the visitors to have a short break whilst going down the stairs. The second reason is to have a clear-cut elevated view of the waterfall feature in the middle. The vegetation will be designed to have this space cleared for the view. After the bridge, the last bit of the stairs would be required to reach the ground floor.

Right when you get to the ground floor, you find yourself in an open area. This gives you a bit of breathing space upon arriving. The pathway here is now at ground floor, where visitors experience the tropical lush nature more close up. They are once again directed to the middle to get a close up, ground level view of the waterfall. The fall of the waterfall is of 10m. It is very difficult to control the splash of the water. It is important that when the visitors are close up to the waterfall, they do not get wet with the splash. This problem was avoided by creating a swamp habitat around the waterfall. Over here, a 4m buffer zone is introduced between the splash of the water and the visitors.

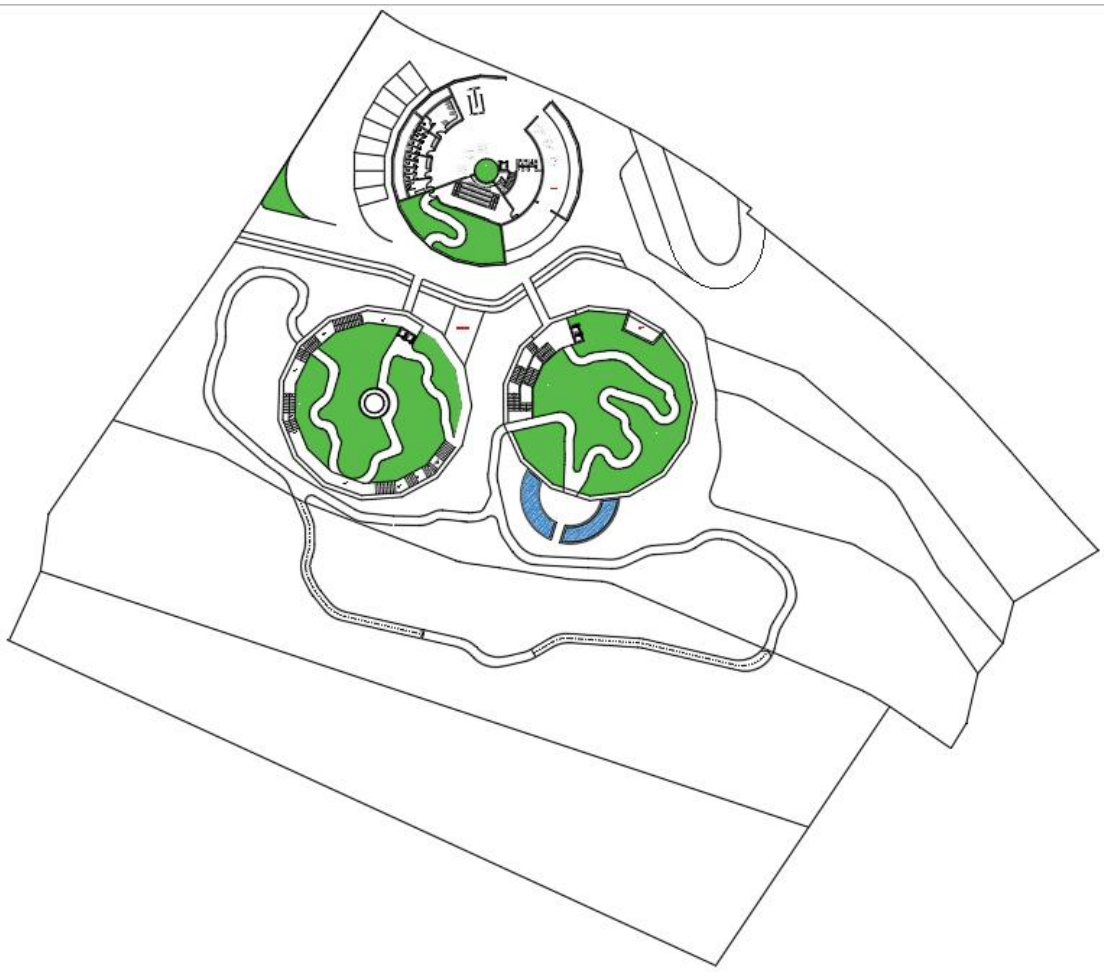
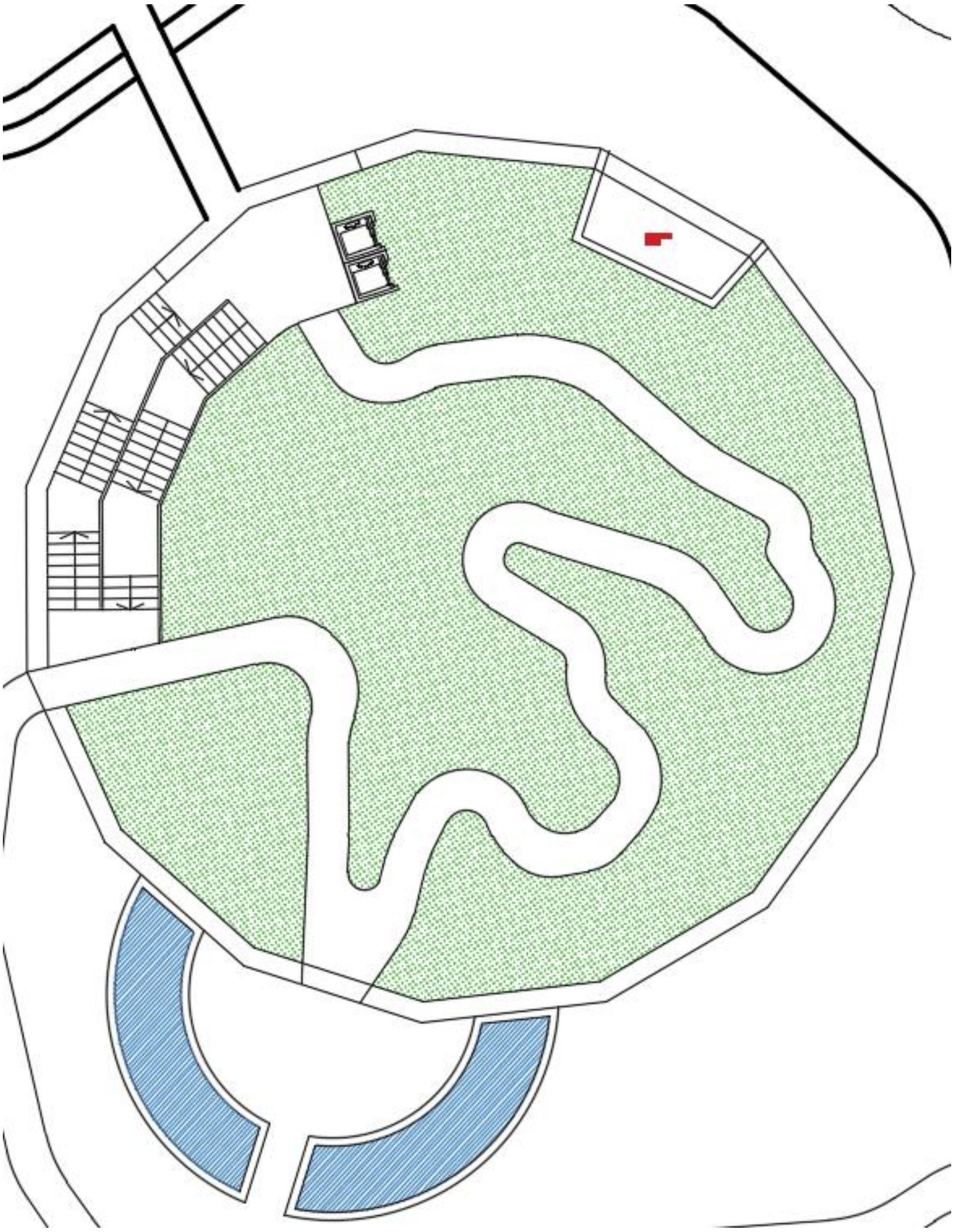


Image: A photo of the landscaped area

The pathway then leads to the outdoor garden. The plants which are harvested here are mainly mediterranean plants which will grow within our natural environment. This area will have several passive recreational spaces for people to enjoy as part of the park. The area is designed to also not force people to have such a calm swift route around the area until they meet the entrance to the next garden. Therefore, a quick path from the exit of the tropical botanical garden to the garden has been designed as an alternative. Despite the outdoor space being on different contours, the area has been designed with ramps to ensure access for all for the entire of the area.

The next structure is a continental botanical garden. The continental botanical garden also has a pathway which leads to outside. However this is just to see a small fountain before directed back inside. After the pathway round the structure, there are staircases and lifts to go back to the top where another timber bridge then take you back to the first structure.



Upon re-entering the structure from the top, the visitors pass through the gift shop and cafeteria completing the whole loop.

Indoor experience- Temperature and Soil Control

Despite creating an environment which naturally prioritizes the plants over the comfort of the viewer, it is important to understand how this can be regulated. Malta's Mediterranean climate is already a very hot and humid climate. This naturally gives the type of microclimate environment a very good starting point to be regulated. It is because of this reason that the micro-environment does not need mechanical ventilation to control the right airflow and temperature. This type of ductwork would take up a lot of space within the inside of the structure, eating out crucial soil space.

The ventilation within this environment is achieved through louvered glass panels at the bottom of the structure. These are manual louvers which can simply be controlled by an employee such as a gardener to ensure there is a pleasant environment for the plants inside. As the hot air rises within the structure, the stack ventilation is achieved through integrated fans within the glass panels to push the air back down and directed to the hole in the curvilinear roof, which also has a two-fold function aiding ventilation.

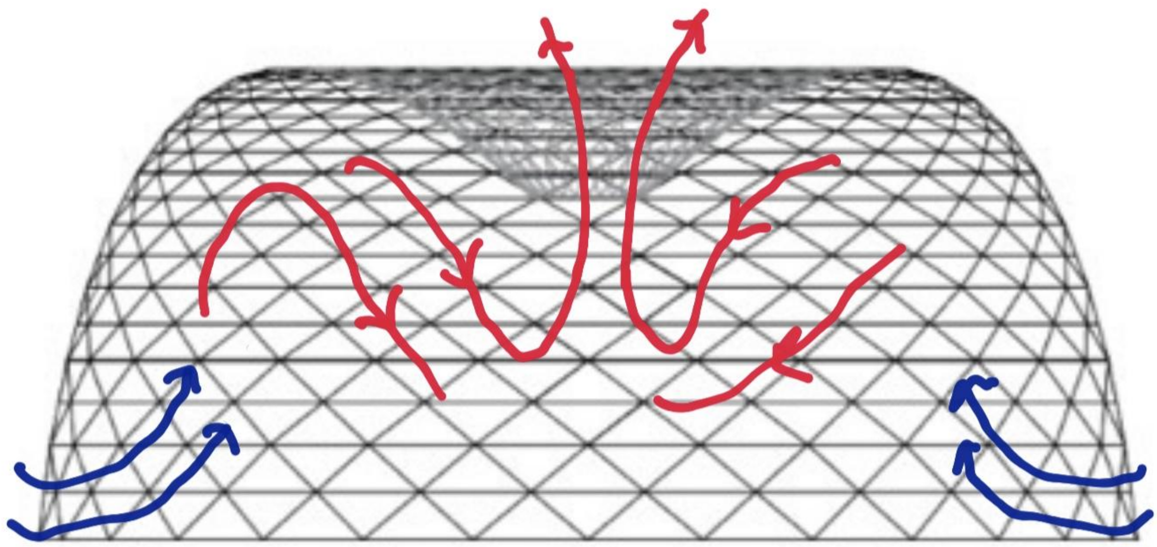


Image: A sketch of how air is circulated within the structure

In the cooler winter months, the inside may need to be heated. This can be done by carefully installed radiators around the structure, heating up the environment.

The soil in itself needs to be maintained in an artificial manner. This is because the type of plants which grow there will not be plants which grow in the mediterranean. Therefore the blinding layer between the soil and the rock acts as a barrier between. The rock is a mediterranean rock (globigerina limestone) which means it inherently will allow plants and vegetation to grow based on that factor and not anything tropical related.

Node + Glass design

The connections between the members of the structure are taken to be fixed connections. This is because when the connections were designed as pinned, the deformations were far too large. Importantly, glass is a brittle material, meaning slight deformations can break the glass. The splice in between the nodes had to be thought out carefully. This is because within a node, 6 members will be intersecting (3 on each side). Therefore, the placement of bolts is purposely done and modelled such that an inclined section will not be in the same location as where a proposed bolt is.

Originally, a splice between the RHS sections and central node was designed to achieve the fixed connection. It was through this detailing stage that the decision was taken to switch to CHS sections. A much cleaner detail was achieved with CHS over RHS. This was chosen as it would be the easiest option to transport and bolt without onsite welding. Also the largest CHS sections are not more than 3m, meaning they can easily be transported on site and then bolted. Also this method simplifies the several complexities and geometries to be done in a controlled manner (prefabricated environment). In reality, the structure can be brought on site and erected like an orange peel. This means that its vertical height can be split up into 3 distinct height (ensuring it fits in the length of a trailer) and split per node (30 nodes total). This means that 90 elements will be brought on site and spliced together. The internal nodes which have been brought in by the structure would have been pre-welded already. This will also allow for a much easier construction and deconstruction process.

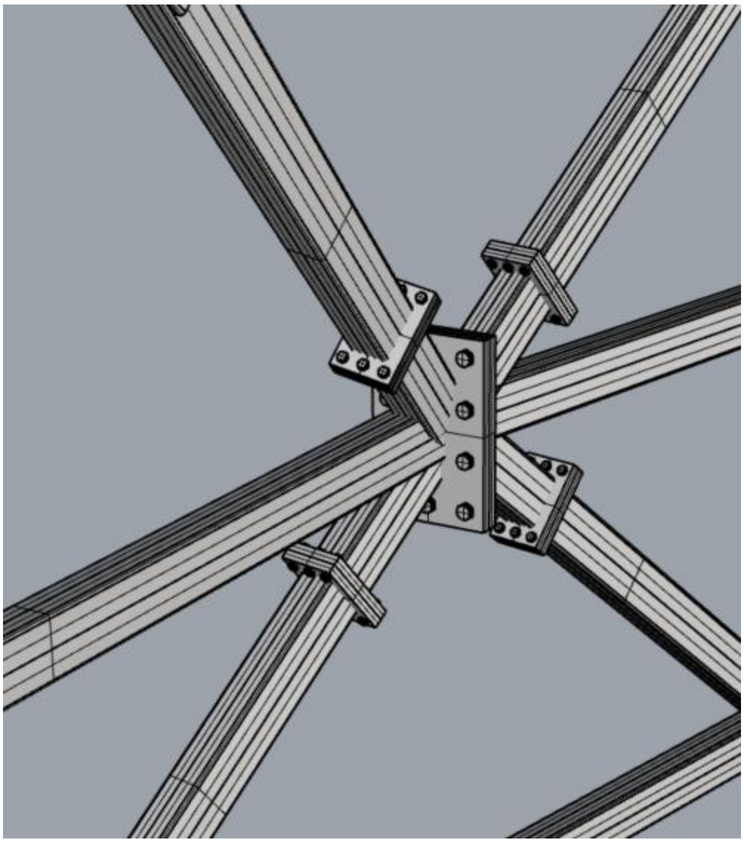


Image: A photo of the node splice for RHS sections

Since the structure is circular, the nodes are radially symmetrical, indicating that the geometries of each respective node will only change level after level.

In tangent with node design, the glass design had to be taken into consideration with this detail. This is because since the geometry in itself is very complex, it is important to try simplify fittings and not redo the complex geometries with the glass fittings. By this I mean that an aluminium mullion frame offset from the structural frame of the building will complicate matters. This is also without taking into consideration that the mullion will need to pass over the splice of the nodes. A mullion in itself shouldn't be notched as it loses a lot of is function like this. These complications led to the general understanding that spider glass fittings are a better alternative than mullions to support the glass.

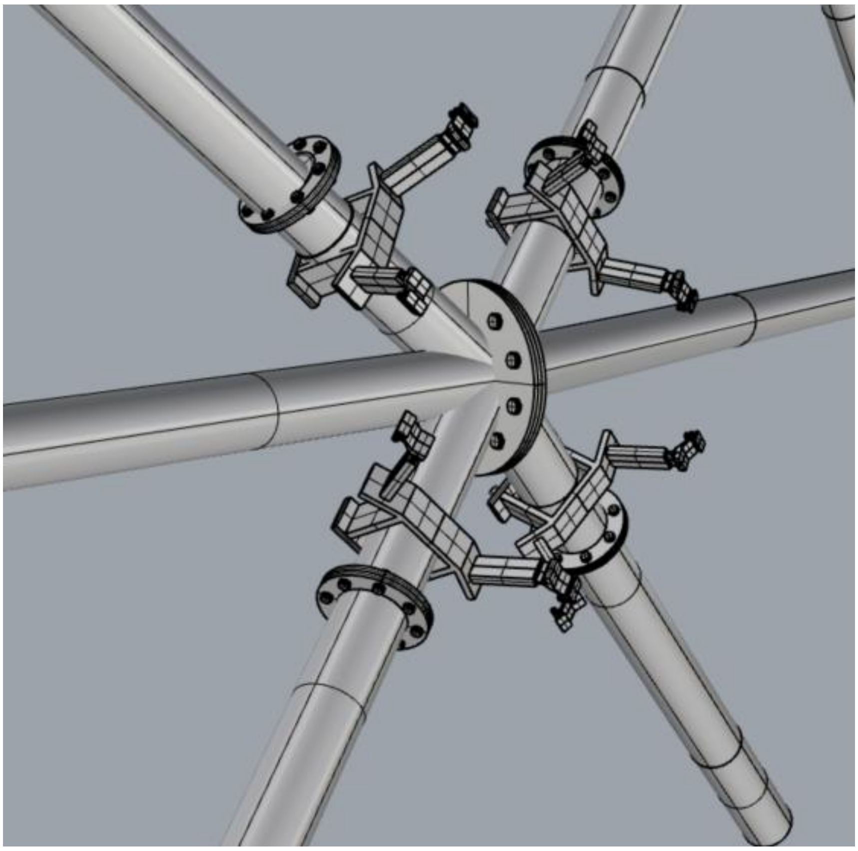


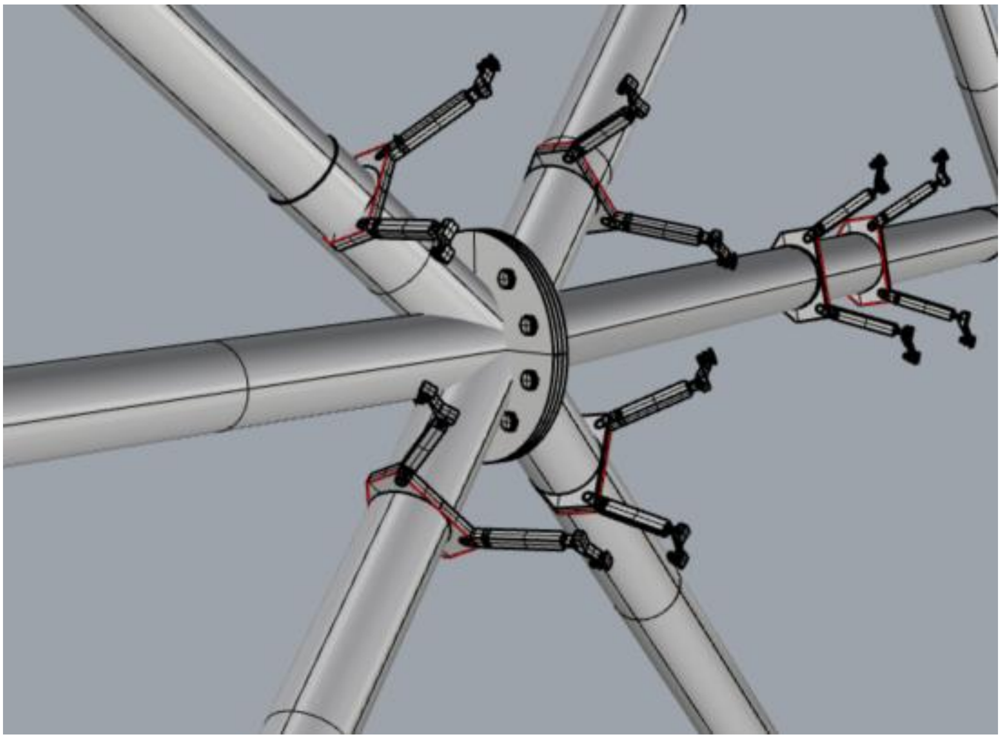
Image: A photo of the CHS splice with spider glass attached to a plate

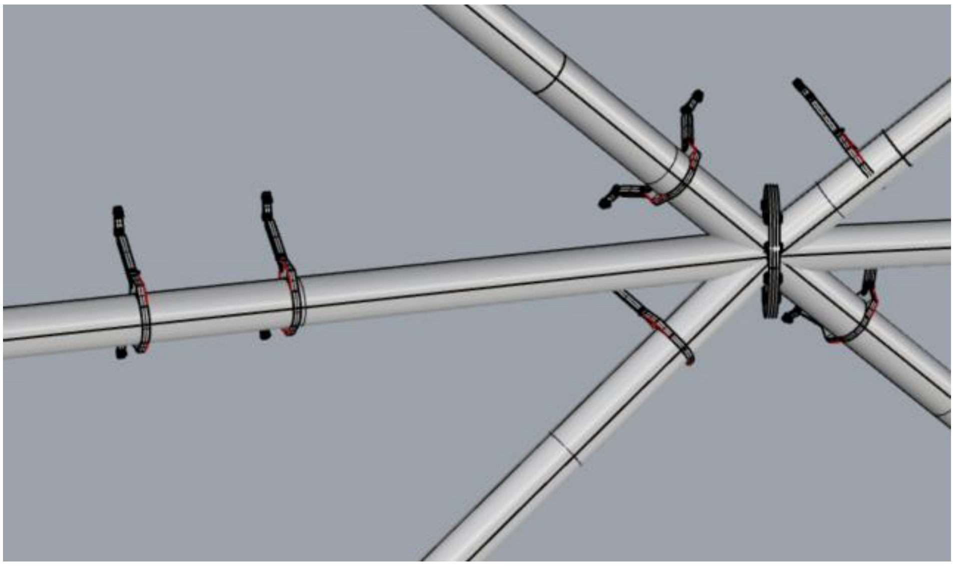
Another obstacle to overcome when it came to using spider glass is that they are normally standardly produced by manufacturers. This means that the arm of the spider glass isnt normally adjusted to the desired length and angle. Despite the possibility of this, custom making the spider glass fitting for every level would be very expensive.

The final solution relating to the glass is placing a steel plate between the CHS splice. This plate will have a pinned connection attaching a steel arm to the plate. This allows a custom length steel arm to rotate several angles. The steel arm will have the spider glass attached to it. This solves the complexity of the problem by having a custom made steel arm over a custom made spider glass fitting. The steel arm is locked in a particular angle through a key which will then restrict the rotation of the steel arm. The spider glass fitting also is designed to allow angular glass panes to support.

Despite the desire to place these spider fittings at every node, it cant solely be the case. This is because at the bottom of the structure, the glass panels will be too large to transport and manouver on site. This has resulted in an additional set of spider glass in the middle of the node to essentially divide the panel into 2.

The final design of the splice-spider glass is such that the splice is placed in between the CHS section. This is done through the use of stiffeners and plates. an access hatch is placed in this area to allow for the tightening and unscrewing of the sections in the case of dismantling or arranging.





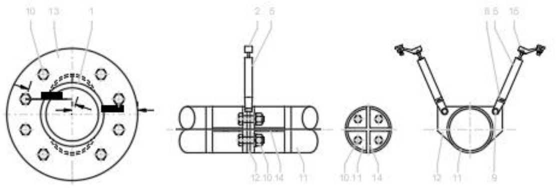
Images: Photos of the final design of the CHS splices with the Spider Glass fittings

DETAILS

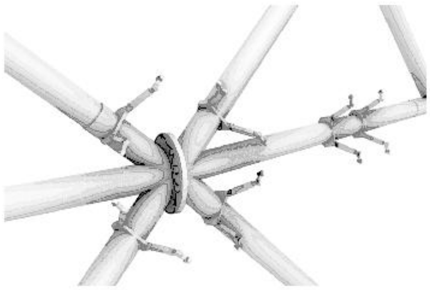
1. GLASS DETAIL

1.1 NODE SPLICES AND SPIDER GLASS ATTACHMENT

SCALE 1:5

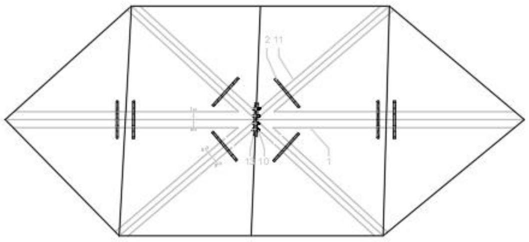


1.2 3D VIEW CONNECTION



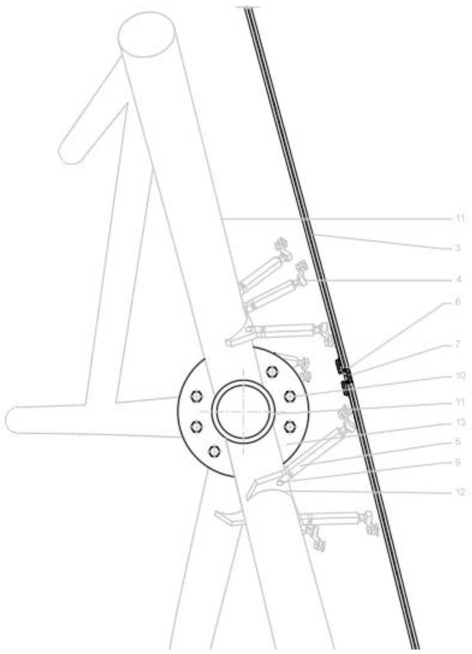
1.3 ELEVATION

SCALE 1:20



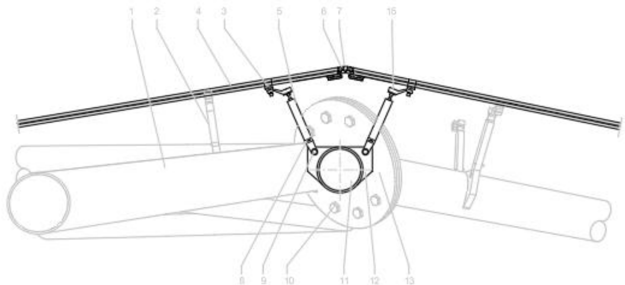
1.4 SECTION A-A'

SCALE 1:5



1.5 SECTION B-B'

SCALE 1:5



1. CHS 193.7x16mm S355 SECTION WITH C5 ANTI CORROSIVE COATINGS
2. SPIDER GLASS
3. SCREW BOLT FOR SPIDER GLASS CONNECTION
4. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
5. METAL PROP TO CONTROL HEIGHT OR GLASS
6. SILICON SEAL
7. EXTRUDED SILICON SEAL
8. KEY TO TIGHTEN PIN CONNECTION
9. PIN CONNECTION
10. M20 G8.8 BOLTS FOR NODE SPLICE
11. CHS 139.7X6.3 S355 WITH C5 ANTI CORROSIVE COATINGS
12. S455 5mm THICK PLATE FOR SPIDER GLASS CONNECTION
13. DIAM. 400mm S355 PLATE FOR NODE CONNECTION
14. 10mm STIFFENER
15. SPIDER GLASS FITTING

Roof Design

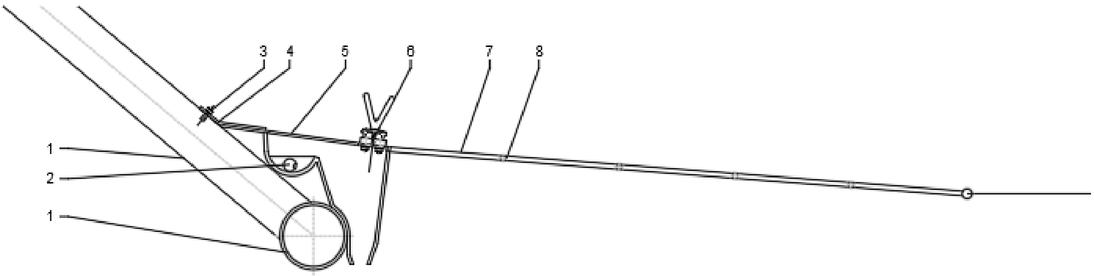
The roof design is very important to understand how the waterfall works and also how the roof deals with rainwater.

Regarding the waterfall, this works through an overflow feature. A pipe is connected within the CHS structural member. This will be transferring water from the source to the top of the waterfall feature. The pipe then will constantly be pumping out water from the source (reservoir). The pipe is evenly spread out around the perimeter of the circle within a built in aluminium gutter-like cover. When this is filled up, the water will start to overflow. The rate at which the water will be constantly overflowed will be proportional the speed of the waterfall. The water is funnelled for a controlled output.

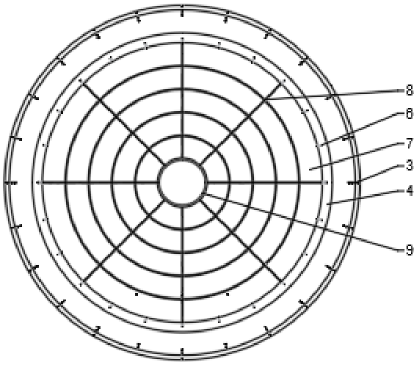
The middle of the roof is open. This is for 2 main reasons. Primarily, the curvilinear shape of the roof allows for a much larger catchment area of rainfall. The rainfall is naturally directed to this centre piece. As the water flows to this open roof, it falls from the centre piece to the reservoir below. At this point the rainwater and the water from the waterfall feature meet with eachother.

The roof structure between the CHS structural members was designed to be PTFE. The decision was between ETFE and PTFE however the “bubble” finish of ETFE was not a feature which was desired. The geometry of the roof structure also didn’t particularly match the function of standard ETFE modules either. The PTFE is supported through a series of purlins and central compression ring to keep the material taught. An important element in the design of such roof structures is to include a protector against birds. This will prevent birds from resting on the edge of the roof and pecking against the roofing material.

Overall, the bolting and cover plates were kept symmetrical to keep a clean finish or the roof. The bolts used were through bolts to reach to the other side of the section.



1. CHS 139.7x6.3 S355 SECTION WITH C5 ANTI-CORROSIVE COATING
2. WATER PIPE TO CREATE ARTIFICIAL WATERFALL EFFECT
3. BOLT
4. WELDED PLATE BETWEEN ALUMINIUM COVER PLATE AND BEAM
5. ALUMINIUM CVER PLATE WITH FUNNEL TO DIRECT WATER
6. BIRD PROTECTOR
7. PTFE ROOF
8. PURLINS TO SUPPORT PTFE
9. COMPRESSION BEAM TO KEEP PTFE TAUT
10. HOLE TO ALLOW WATER TO PASS THROUGH



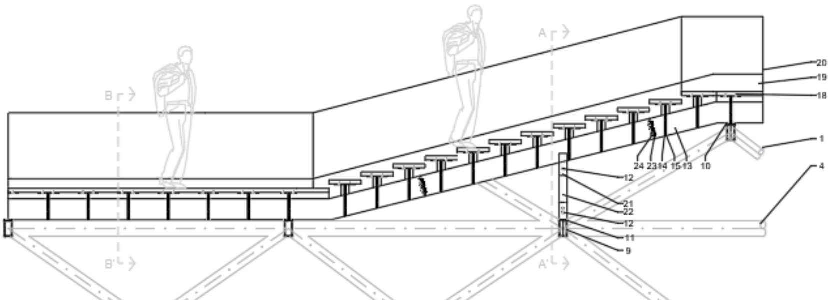
Cantilever Detail

The stairs upon entrance to the structure to ground floor are supported by being cantilevered from the nodes of the structure. This is done because apart from giving you the aesthetic feeling as though you are floating when going down the stairs, it also saves a lot of complications when constructing the strip footing in the foundation.

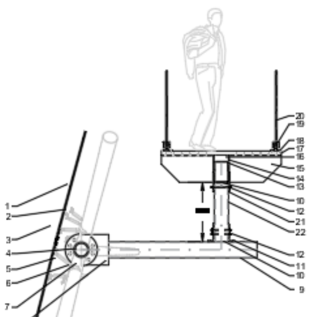
The cantilever is connected to the node though a crocodile nose section. This is essentially a plate which is welded to the RHS allowing for a plate to connect to the section.

The RHS section now induces a moment in another plane for the node. This required additionally stiffness and in fact the section sizes were this cantilever was attached to had to be stiffer.

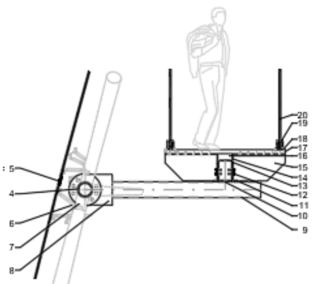
The stairs height was aligned to the respective heights of the nodes. The span was reduced between one height to another by using internal props for the staircase. The stairs are supported by an RHS section. The additional length between this RHS section and the timber paving of the platform is supported by stiffeners. This provides enough rigidity for the staircase. The internal prop is also an RHS section and it was sized to match the width of the RHS beam for the staircase. These are connected together with a through bolt so that the RHS section will not need to be castellated.



2.1 ELEVATION
SCALE 1:20



2.2 SECTION A-A'
SCALE 1:50



2.3 SECTION B-B'
SCALE 1:50

1. CHS SECTION S355 139.7x6.3
2. CHS SPLICE
3. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
4. CHS SECTION S355 193.7x16
5. SILICON
6. NODE SPLICE DIAM. 400mm S355 STEEL PLATE
7. M20 G8.8 BOLT
8. CROCODILE NODE 30mm S355 PLATE-RHS CONNECTION
9. CANTILEVERED BEAM S355 RHS 200x100x10
10. SHIMS
11. S355 WEB CLEATS WELDED TO BEAM
12. 180mm M20 THROUGH BOLTS
13. S355 RHS 260x1806.3 STAIRCASE BEAM
14. 10mm WELD BETWEEN STIFFENER AND BEAM (DONE IN PREFABRICATION)
15. S455 10mm STIFFENER
16. STEEL S355 WELDED SPACER
17. 50mm TIMBER STAIRCASE
18. SCREWS
19. GUARD RAIL
20. GLASS RAILING
21. S355 WEB PLATE PRE WELDED TO RHS STAIRCASE BEAM FOR BEAM-COLUMN CONNECTION
22. S355 RHS COLUMN SECTION 180x100x12.5
23. 10mm PLATE FOR RHS BEAM SPLICE
24. M20 BOLT FOR BEAM STAICASE SPLICE

Foundation Detail

The first step in the foundation was to understand what loads and the ground present to deal with. Regarding loading, the foundation will always be in axial compression. This is because the dead-weight of the structure will always exceed the lateral forces caused by the wind. In reality the structure itself isnt high, meaning the wind forces will not be that large.

The ground is globigerina limestone. In theory, despite this being a strong material for foundations, it is also prone to several cracks and discontinuities. This problem will need to be addressed prior to the excavation to create the dislevelling which is wanted. If several cracks and discontunities are present from the boreholes found, adequate interventions like shotcrete or rockbolts will need to be put in place to stabilise the ground further.

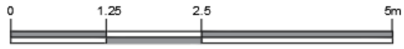
The structure itself is being pinned to the ground with 30 different nodes at ground level. This results in the self-weight of the structure being evenly distributed to the 30 different nodes as 30 different point loads. These form a circular shape and therefore the geometry of the foundation can be used to its advantage by tying these nodes together through a strip footing. The strip footing is placed around 400mm under the ground level. This is because it allowed for a ground slab to be constructed on one side and allowed for a precast drain to be constructed on the other side.

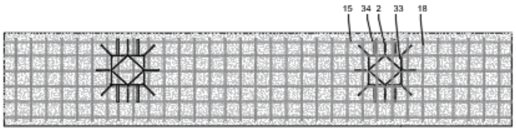
The interaction between the soil and the foundation needed to be analysed. This is because the soil pit being full with soil and adjacent to the foundation may not be an issue. However, in the instance that the soil needs to be excavated, a retaining wall will need to be present to prevent the sliding of the foundation in the presence of rock discontinuity.

The foundation itself can be constructed as the retaining wall. However, this will require a very large volume of concrete, whether precast or in-situ. This is not something desired. Therefore, a barrier between the soil and the foundation will be created and filled with gravel. This will prevent the interaction of the foundation with the excavated face (in the case of no soil) due to being at a larger eccentricity from the edge. This space in between is going to have a ground slab placed on top of it and this will be the maintenance area for workers and gardeners to access the soil from the back.

FOUNDATION DETAIL

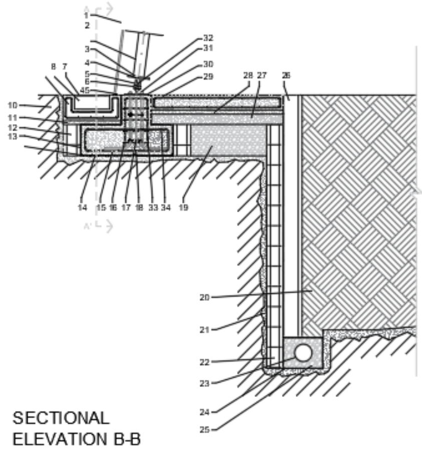
SCALE 1:50





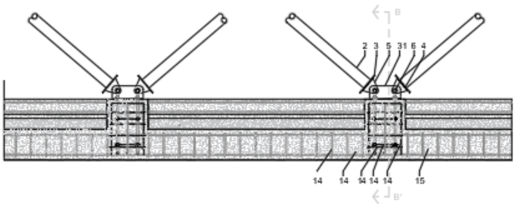
4.2 SECTIONAL PLAN

SCALE 1:50



SECTIONAL
ELEVATION B-B

SCALE 1:50



SECTIONAL ELEVATION A-A'

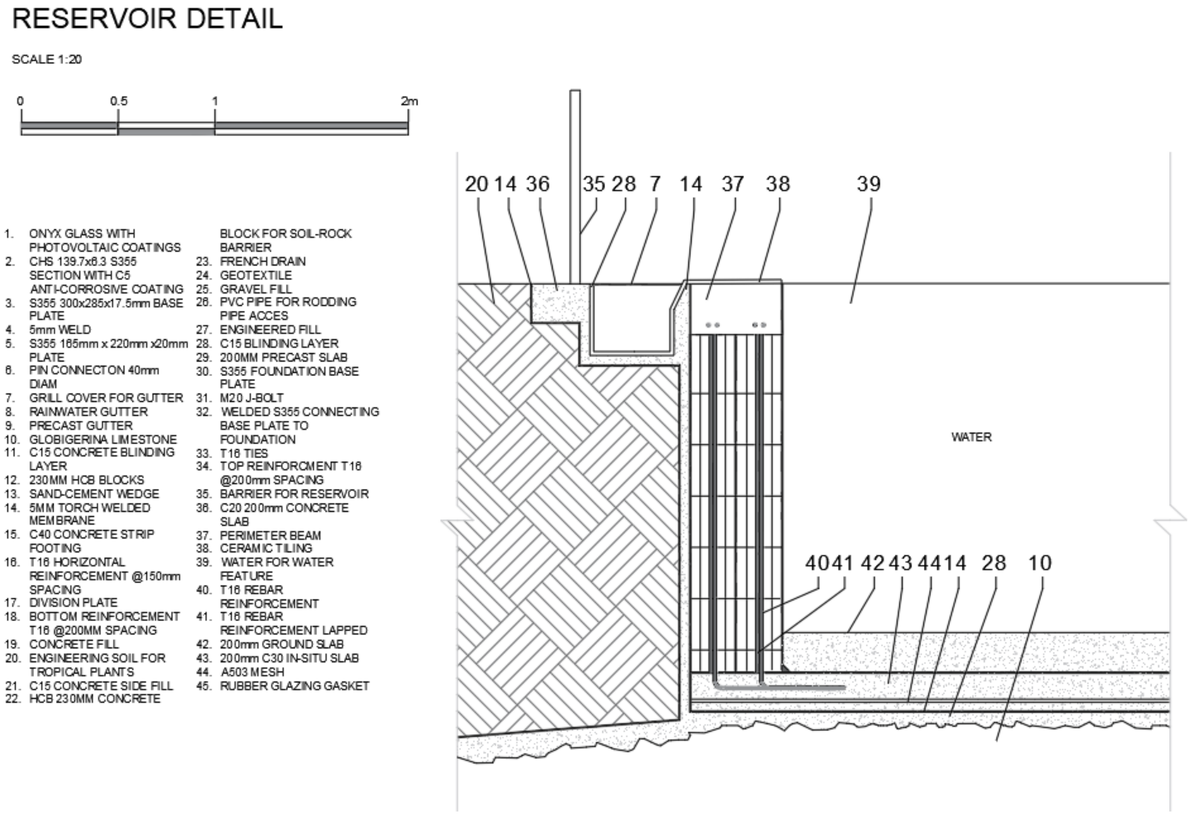
SCALE 1:50

1. ONYX GLASS WITH PHOTOVOLTAIC COATINGS
2. CHS 139.7x6.3 S355 SECTION WITH C5 ANTI-CORROSIVE COATING
3. S355 300x285x17.5mm BASE PLATE
4. 5mm WELD
5. S355 165mm x 220mm x20mm PLATE
6. PIN CONNECTON 40mm DIAM
7. GRILL COVER FOR GUTTER
8. RAINWATER GUTTER
9. PRECAST GUTTER
10. GLOBIGERINA LIMESTONE
11. C15 CONCRETE BLINDING LAYER
12. 230MM HCB BLOCKS
13. SAND-CEMENT WEDGE
14. 5MM TORCH WELDED MEMBRANE
15. C40 CONCRETE STRIP FOOTING
16. T16 HORIZONTAL REINFORCEMENT @150mm SPACING
17. DIVISION PLATE
18. BOTTOM REINFORCEMENT T16 @200MM SPACING
19. CONCRETE FILL
20. ENGINEERING SOIL FOR TROPICAL PLANTS
21. C15 CONCRETE SIDE FILL
22. HCB 230MM CONCRETE BLOCK FOR SOIL-ROCK BARRIER
23. FRENCH DRAIN
24. GEOTEXTILE
25. GRAVEL FILL
26. PVC PIPE FOR RODDING PIPE ACCES
27. ENGINEERED FILL
28. C15 BLINDING LAYER
29. 200MM PRECAST SLAB
30. S355 FOUNDATION BASE PLATE
31. M20 J-BOLT
32. WELDED S355 CONNECTING BASE PLATE TO FOUNDATION
33. T16 TIES
34. TOP REINFORCMENT T16 @200mm SPACING
35. BARRIER FOR RESERVOIR
36. C20 200mm CONCRETE SLAB
37. PERIMETER BEAM
38. CERAMIC TILING
39. WATER FOR WATER FEATURE
40. T16 REBAR REINFORCEMENT
41. T16 REBAR REINFORCEMENT LAPPED
42. 200mm GROUND SLAB
43. 200mm C30 IN-SITU SLAB
44. A503 MESH
45. RUBBER GLAZING GASKET

Reservoir Detail

The reservoir is a very important part of the project for the whole system to work cohesively. This is because it acts as the point where the water from the artificial water feature and possible rainwater from the roof meet. It will be a temporary reservoir for the water. As the water falls, it will overflow to a gutter right adjacent to the ceramic tiling. This will then be directed to the pump room outside of the structure (here another temporary reservoir will be present. This water meets with the water from the gutter detailing with the rainwater from the sides of the structure. This water will then be pumped to the old manoel island tanks which used to carry a substantial amount of fuel. This will be the main reservoir and it is only 80 metres away from the structure and can hold enough water for the required irrigation. More importantly, it is easily accessible from the road, meaning it can be filled up by water thank for easily.

The detail itself is made out of infilled 230mm bricks. This will provide adequate resistance to the water pressures. Membranes are placed around the structure to protect the slabs from the water



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Structural Analysis

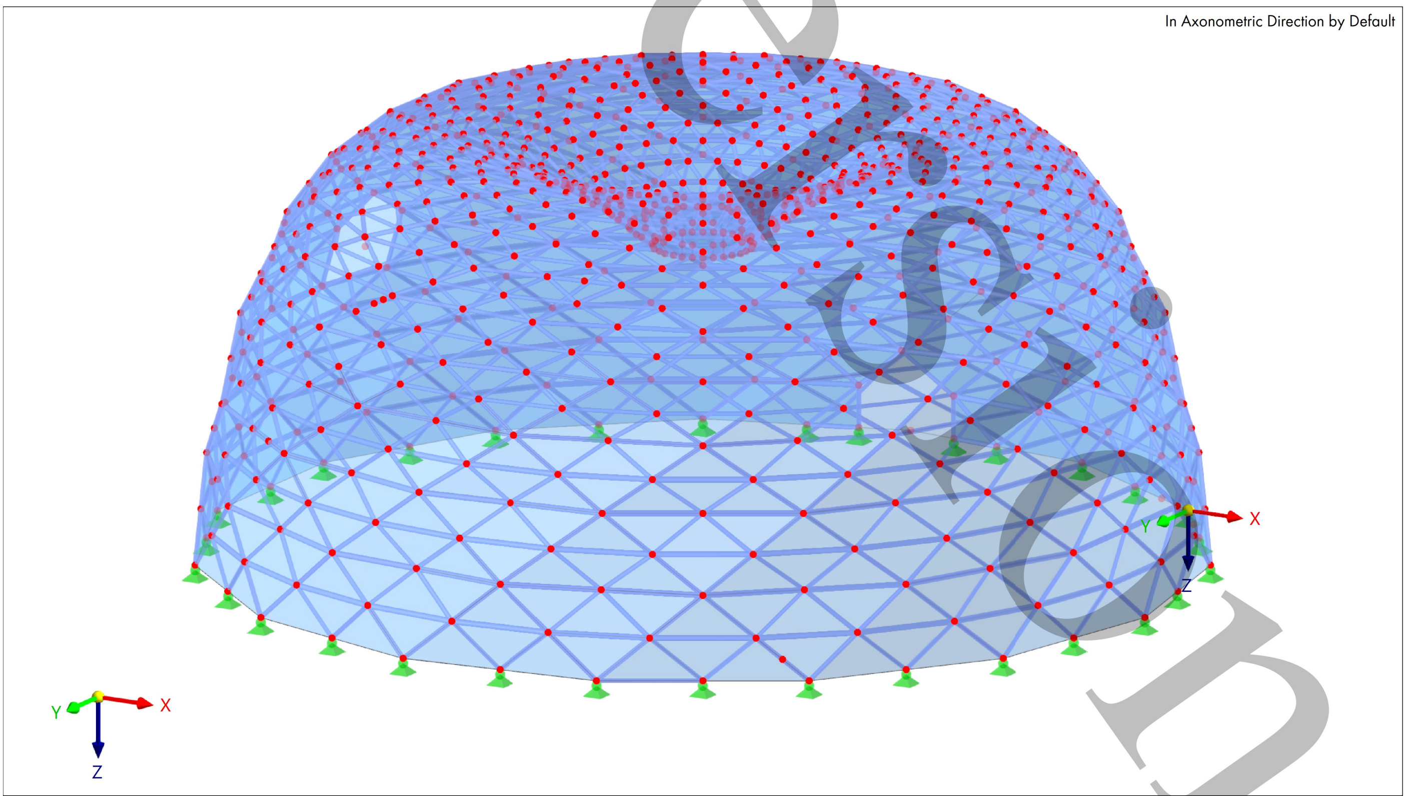
CLIENT

CREATED BY

PROJECT

Chapters

MODEL



CONTENTS

A

MODEL - LOCATION

Location

Country	:	--
Street	:	
Zip / Postal code	:	
City	:	
State	:	
Latitude	:	deg
Longitude	:	deg
Altitude	:	m

1 Basic Objects

1.1 MATERIALS

Legend
Concrete Settings

Material No.	Material Name	Material Type	Analysis Model	Options
3	S355M | Isotropic | Linear Elastic	Steel	Isotropic | Linear Elastic	
4	S355N | Isotropic | Linear Elastic	Steel	Isotropic | Linear Elastic	
5	C30/37 | Isotropic | Linear Elastic	Concrete	Isotropic | Linear Elastic	⚙
6	C35/45 | Isotropic | Linear Elastic	Concrete	Isotropic | Linear Elastic	⚙
7	C35/45 | Isotropic | Linear Elastic	Concrete	Isotropic | Linear Elastic	⚙
8	S355N | Isotropic | Linear Elastic	Steel	Isotropic | Linear Elastic	

2 Types for Nodes

2.1 NODAL SUPPORTS

Support No.	Nodes No.	Coordinate System	Translation Spring [kN/m] $C_{u,X}$	$C_{u,Y}$	$C_{u,Z}$	Rotation Spring [kNm/rad] $C_{\varphi,X}$	$C_{\varphi,Y}$	$C_{\varphi,Z}$
1	☑☑☑ ☐☐☑ 946,949	1 - Global XYZ	☒	☒	☒	☐	☐	☒
6	☑☑☑ ☐☐☑ 871,874,877,880,886,889,892,895,898,901,904,907,910,913,916-930	1 - Global XYZ	☒	☒	☒	☐	☐	☒

3 Types for Steel Design

3.1 EFFECTIVE LENGTHS

Legend
Principal Section Axes y/u and z/v

No.	Description	Symbol	Value	Unit	Options
1	Standard (Members : 1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,1601-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3415)				
	Assigned to members		1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,1601-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3415		⚑
	Assigned to member sets				
	Flexural buckling about y		☒		
	Flexural buckling about z		☒		
	Torsional buckling		☒		
	Lateral-torsional buckling		☒		
	Determination of M_{cr}		Eigenvalue		
	Intermediate nodes		☐		
	Different properties		☒		

3.1.1 EFFECTIVE LENGTHS - NODAL SUPPORTS

No.	Node Seq. No.	Fixed in z/v	y/u	Rest. About x	z/v	Warping ω	Nodes	Eccentricity Type	e_z [mm]
1	Standard (Members : 1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,1601-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3415)								
	Start	☒ 2	☒	☒	☐	☐	1-607,609-825,827-876,878,880-882,884,886-930,932-940	None	
	End	☒ 2	☒	☒	☐	☐	1-438,440-607,609-876,878-882,884-915,923,928,932-940	None	

3.1.2 EFFECTIVE LENGTHS - NODAL SUPPORTS - SPRING CONSTANTS

No.	Node Seq. No.	Springs $c_{y/u}$ [kN/m]	$c_{\varphi,x}$ [kNm/rad]	$c_{\varphi,z/v}$ [kNm/rad]	Warping c_ω [kNm³/rad]	Nodes
1	Standard (Members : 1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,1601-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3415)					
	Start					1-607,609-825,827-876,878,880-882,884,886-930,932-940
	End					1-438,440-607,609-876,878-882,884-915,923,928,932-940

3.1.3 EFFECTIVE LENGTHS - FACTORS

No.	Segment No.	Flexural Buckling $k_{y/u}$ [--]	$k_{z/v}$ [--]	k_y [--]	k_z [--]	Torsional Buckling k_T [--]	Critical Moment M_{cr} [kNm]
1	Standard (Members : 1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,1601-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3415)						
	1	1.00	1.00			1.00	

4 Load Cases & Combinations

4.1 LOAD CASES

LC No.	Settings	Value	Unit	To Solve
1	Qw WIND LOAD			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Action category	Qw Wind		
2	QI H IMPOSED LOAD			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Action category	QI H Imposed loads - category H: roofs		
3	G DEAD WEIGHT			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Action category	G Permanent		
	Self-weight - Factor in direction X	0.000	--	
	Self-weight - Factor in direction Y	0.000	--	
	Self-weight - Factor in direction Z	1.000	--	
4	Qw UPLIFT			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Action category	Qw Wind		
5	AE SEISMIC			
	Analysis type	Static Analysis		☒
	Static analysis settings	SA1 - Geometrically linear		
	Action category	AE Seismic actions		

4.2 STATIC ANALYSIS SETTINGS

Settings No.	Description	Symbol	Value	Unit
1	Geometrically linear			
	Analysis type		Geometrically linear	
	Modify standard precision and tolerance settings		☐	
	Modify loading by multiplier factor		☐	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
2	Second-order (P-Δ) | Picard | 100 | 1			
	Analysis type		Second-order (P-Δ)	
	Iterative method for nonlinear analysis		Picard	
	Maximum number of iterations		100	
	Number of load increments		1	
	Modify standard precision and tolerance settings		☐	
	Ignore all nonlinearities		☐	
	Modify loading by multiplier factor		☐	
	Consider favorable effect due to tension in members		☒	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Refer internal forces to deformed structure		☒	
	Refer internal forces to deformed structure for normal forces		☒	
	Refer internal forces to deformed structure for shear forces		☒	
	Refer internal forces to deformed structure for moments		☒	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
	Stability check based on deformation rate		☐	
3	Large deformations | Newton-Raphson | 100 | 1			
	Analysis type		Large deformations	
	Iterative method for nonlinear analysis		Newton-Raphson	
	Maximum number of iterations		100	
	Number of load increments		1	
	Modify standard precision and tolerance settings		☐	
	Ignore all nonlinearities		☐	
	Modify loading by multiplier factor		☐	
	Consider favorable effect due to tension in members		☒	
	Try to calculate unstable structure		☐	
	Displacements due to member load of type 'Pipe internal pressure' (Bourdon effect)		☐	
	Method for equation system		Direct	
	Plate bending theory		Mindlin	
	Activate mass conversion to load		☐	
	Asymmetric direct solver		☒	
	Equilibrium for undeformed structure		☐	
	Stability check based on deformation rate		☐	

4.3 COMBINATION WIZARDS

Wizard No.	Settings	Value
1	Load combinations | SA2 - Second-order (P-Δ) | Picard | 100 | 1	
	Assigned to	DS 1-4
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA2 - Second-order (P-Δ) | Picard | 100 | 1
	Consider imperfection case	☒
	Consider initial state	☐
	Structure modification enabled	☐
	Generate same load combinations without imperfection case	☐
	Consider construction stages	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐

4.3 COMBINATION WIZARDS

Wizard No.	Settings	Value
2	Load combinations | SA1 - Geometrically linear	
	Assigned to	
	Generate combinations	Load combinations (non-linear analysis)
	Static analysis settings	SA1 - Geometrically linear
	Consider imperfection case	☐
	Consider initial state	☐
	Structure modification enabled	☐
	Consider construction stages	☐
	User-defined action combinations	☐
	Favorable permanent actions	☐
	Reduce number of generated combinations	☐

5 Guide Objects

5.1 COORDINATE SYSTEMS

System No.	Type	Coordinates Symbol	Coordinates Value	Unit	Rotation Sequence	Rotation Symbol	Rotation Value	Rotation Unit	Comment
1	Global XYZ								
2	3 Points | 0.000, 0.000, 0.000 m | 1.000, 0.000, 0.000 m | 1.000, 0.000, -1.000 m								
	3 Points	X_0	0.000	m					
		Y_0	0.000	m					
		Z_0	0.000	m					
		X_1	1.000	m					
		Y_1	0.000	m					
		Z_1	0.000	m					
		X_2	1.000	m					
		Y_2	0.000	m					
		Z_2	-1.000	m					

6 Parts List

6.1 PARTS LIST - ALL BY MATERIAL

Parts Lists

Material No.	Material Name	Object Type	Tot. Coating C_Σ [m²]	Tot. Volume V_Σ [m³]	Total Mass M_Σ [kg]
3	S355M	Members	2503.090	17.488	137278.8
Total			2503.090	17.488	137278.8
Σ Total			2503.090	17.488	137278.8

7 Static Analysis Results

7.1 MEMBERS - INTERNAL FORCES BY SECTION

Static Analysis

Section No.	Member No.	Node No.	Location x [m]		Forces [kN] N	V_y	V_z	Moments [kNm] M_T	M_y	M_z	Member Comment Cor. Loading
	Qw LC1 - WIND LOAD										
	Total max/min values with corresponding values										
21	2889	887	0.000	N	154.37	-2.59	0.59	-0.09	-0.85	-2.20	
21	2890	880	2.189		-171.72	1.43	0.99	-0.07	1.94	-1.14	
22	2190	879	3.368	V_y	46.20	5.30	0.35	0.13	0.32	-7.82	
22	1595	882	0.000		14.08	-5.34	-1.03	0.03	1.49	-8.58	
21	3412	407	0.000	V_z	36.50	-2.20	3.41	-0.43	-2.95	-1.69	
21	3422	885	0.000		-111.28	-1.32	-2.99	-0.55	3.51	-0.87	
21	3419	919	0.000	M_T	0.00	0.00	1.28	0.72	-1.03	0.00	
21	3421	884	0.000		111.67	-1.60	2.91	-0.59	-3.36	-1.10	
21	3422	885	0.000	M_y	-111.28	-1.32	-2.99	-0.55	3.51	-0.87	
21	3421	884	0.000		111.67	-1.60	2.91	-0.59	-3.36	-1.10	
22	2190	881	0.000	M_z	47.73	4.42	0.35	0.13	-0.87	8.55	
22	1595	882	0.000		14.08	-5.34	-1.03	0.03	1.49	-8.58	
	QI H LC2 - IMPOSED LOAD										
	Total max/min values with corresponding values										

7.1 MEMBERS - INTERNAL FORCES BY SECTION

Static Analysis

Section No.	Member No.	Node No.	Location x [m]		Forces [kN] N	V_y	V_z	Moments [kNm] M_T	M_y	M_z	Member Comment Cor. Loading
22	2886	620	0.000	N	111.03	-1.38	-0.53	0.57	-0.43	-1.01	
21	3140	169	0.000		-177.15	-0.09	-0.37	0.16	-1.67	-0.08	
21	2514	235	0.000	V_y	-49.45	5.93	-1.45	-0.99	0.84	4.27	
21	759	572	0.000		-48.33	-6.36	1.51	1.37	-1.30	-3.43	
21	689	558	0.000	V_z	-66.03	0.70	10.03	1.47	-4.01	0.28	
21	3040	170	0.000		-11.82	-1.63	-9.15	-0.84	1.54	-0.75	
21	1889	239	0.000	M_T	-88.62	-6.17	2.31	3.62	-2.29	-2.86	
21	3092	774	0.000		-81.38	-2.90	-1.30	-3.63	2.15	-2.23	
21	689	161	1.077	M_y	-66.03	0.70	9.36	1.47	6.43	-0.47	
21	3040	162	1.077		-11.81	-1.64	-8.40	-0.84	-7.91	1.02	
22	2703	518	3.292	M_z	75.73	-3.45	1.52	-0.14	1.34	5.80	
22	2719	627	0.000		66.79	-3.51	-0.64	-0.09	-0.08	-5.84	
	G LC3 - DEAD WEIGHT										
	Total max/min values with corresponding values										
21	230	231	0.000	N	61.12	0.00	0.23	-0.15	0.24	-0.13	
21	3171	204	0.000		-108.33	-0.05	-0.29	0.10	-1.00	-0.05	
21	2514	235	0.000	V_y	-29.55	3.57	-1.03	-0.61	0.56	2.58	
21	759	572	0.000		-28.92	-3.84	0.89	0.84	-0.81	-2.06	
21	689	558	0.000	V_z	-40.23	0.44	6.05	0.89	-2.42	0.18	
21	3174	215	0.000		-7.23	-1.01	-5.56	-0.52	0.95	-0.46	
21	1889	239	0.000	M_T	-53.93	-3.76	1.34	2.21	-1.37	-1.74	
21	3092	774	0.000		-49.70	-1.78	-0.75	-2.21	1.33	-1.36	
21	689	161	1.077	M_y	-40.23	0.44	5.76	0.89	3.94	-0.29	
21	3174	207	1.077		-7.23	-1.01	-5.26	-0.52	-4.88	0.63	
22	2703	518	3.292	M_z	39.37	-1.79	1.45	-0.07	0.98	3.00	
22	2719	627	0.000		34.73	-1.82	-1.05	-0.05	0.35	-3.02	
	Qw LC4 - UPLIFT										
	Total max/min values with corresponding values										
22	2886	620	0.000	N	83.27	-1.03	-0.40	0.43	-0.32	-0.76	
21	3140	169	0.000		-132.86	-0.07	-0.28	0.12	-1.25	-0.06	
21	2514	235	0.000	V_y	-37.09	4.44	-1.08	-0.74	0.63	3.20	
21	759	572	0.000		-36.25	-4.77	1.14	1.03	-0.97	-2.57	
21	689	558	0.000	V_z	-49.52	0.52	7.52	1.10	-3.01	0.21	
21	3040	170	0.000		-8.87	-1.23	-6.87	-0.63	1.16	-0.56	
21	1889	239	0.000	M_T	-66.46	-4.63	1.73	2.71	-1.72	-2.14	
21	3092	774	0.000		-61.03	-2.17	-0.98	-2.72	1.61	-1.67	
21	689	161	1.077	M_y	-49.52	0.52	7.02	1.10	4.82	-0.35	
21	3040	162	1.077		-8.86	-1.23	-6.30	-0.63	-5.94	0.76	
22	2703	518	3.292	M_z	56.80	-2.59	1.14	-0.10	1.00	4.35	
22	2719	627	0.000		50.10	-2.63	-0.48	-0.07	-0.06	-4.38	
	AE LC5 - SEISMIC										
	Total max/min values with corresponding values										
21	1	1	0.000	N	0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000		0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000	V_y	0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000		0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000	V_z	0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000		0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000	M_T	0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000		0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000	M_y	0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000		0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000	M_z	0.00	0.00	0.00	0.00	0.00	0.00	
21	1	1	0.000		0.00	0.00	0.00	0.00	0.00	0.00	
	ULS DS1 - ULS (STR/GEO) - Permanent and transient - Eq. 6.10										
	Total max/min values with corresponding values										
21	230	231	0.000	N	327.80	-0.23	0.53	-0.81	1.38	-0.81	CO6
21	3140		0.643		-544.63	-0.23	-1.26	0.49	-6.06	-0.31	CO6
21	2514		0.735	V_y	-149.00	18.71	-6.12	-3.17	-1.37	-0.22	CO6
21	759		0.514		-143.73	-20.10	3.64	4.45	-1.98	-0.43	CO6
21	689		0.070	V_z	-212.97	2.92	32.17	4.06	-10.43	0.85	CO6
21	3040	170	0.000		-42.35	-5.79	-28.05	-3.28	3.84	-2.35	CO6
21	1889	756	1.174	M_T	-280.29	-18.72	6.84	12.04	0.78	13.95	CO6
21	3092	774	0.000		-261.14	-9.25	-3.14	-12.04	6.87	-7.27	CO6
21	689	161	1.077	M_y	-213.12	2.89	29.47	4.03	21.11	-2.21	CO6
21	3090	202	1.077		-43.53	-5.60	-25.62	-3.39	-25.18	3.82	CO6
22	2703	518	3.292	M_z	217.21	-10.39	5.31	-0.40	4.24	16.99	CO6
22	2719	627	0.000		192.08	-10.47	-2.77	-0.28	0.25	-17.02	CO6

7.1 MEMBERS - INTERNAL FORCES BY SECTION

Static Analysis

Section No.	Member No.	Node No.	Location x [m]		Forces [kN] N	V_y	V_z	Moments [kNm] M_T	M_y	M_z	Member Comment Cor. Loading
	S Ch DS2 - SLS - Characteristic										
	Total max/min values with corresponding values										
22	2886	620	0.000	N	220.30	-2.55	-1.69	1.16	-0.56	-1.67	CO12
21	3140	169	0.000		-370.68	-0.13	-1.80	0.33	-3.20	-0.26	CO12
21	2514		0.735	V_y	-102.04	12.61	-4.15	-2.13	-0.91	-0.15	CO12
21	759		0.514		-98.78	-13.55	2.49	2.98	-1.33	-0.30	CO12
21	689	558	0.000	V_z	-142.72	1.81	21.56	2.87	-8.54	0.67	CO12
21	3040	170	0.000		-27.48	-3.78	-19.09	-2.08	2.82	-1.59	CO12
21	1889	756	1.174	M_T	-188.97	-12.81	4.24	7.98	0.36	9.40	CO12
21	3092	774	0.000		-175.36	-6.22	-2.32	-7.99	4.62	-4.85	CO12
21	689	161	1.077	M_y	-142.77	1.81	19.93	2.85	14.08	-1.33	CO12
21	3090	202	1.077		-28.21	-3.69	-17.54	-2.13	-16.96	2.44	CO12
22	2703	518	3.292	M_z	148.87	-7.01	3.68	-0.28	2.92	11.56	CO12
22	2719	627	0.000		131.55	-7.09	-1.96	-0.19	0.21	-11.60	CO12
	S Fr DS3 - SLS - Frequent										
	Total max/min values with corresponding values										
21	230	231	0.000	N	77.70	-0.01	0.25	-0.19	0.31	-0.18	CO15
21	3171	204	0.000		-135.52	-0.06	-0.47	0.12	-1.22	-0.07	CO15
21	2514		0.709	V_y	-37.11	4.51	-1.53	-0.77	-0.30	0.07	CO15
21	759		0.514		-36.12	-4.85	0.94	1.07	-0.48	-0.11	CO15
21	689	558	0.000	V_z	-50.99	0.59	7.68	1.09	-3.06	0.23	CO15
21	3174	215	0.000		-9.46	-1.30	-6.96	-0.69	1.13	-0.58	CO15
21	1889	756	1.174	M_T	-68.02	-4.70	1.39	2.82	0.06	3.38	CO15
21	3092	774	0.000		-62.89	-2.24	-0.91	-2.82	1.67	-1.73	CO15
21	689	161	1.077	M_y	-50.99	0.59	7.24	1.09	5.01	-0.41	CO15
21	3174	207	1.077		-9.48	-1.30	-6.53	-0.69	-6.14	0.82	CO15
22	2703	518	3.292	M_z	50.69	-2.33	1.68	-0.09	1.18	3.89	CO15
22	2719	627	0.000		44.75	-2.37	-1.15	-0.07	0.33	-3.91	CO15
	S Qp DS4 - SLS - Quasi-permanent										
	Total max/min values with corresponding values										
21	230	231	0.000	N	62.18	-0.01	0.21	-0.15	0.24	-0.14	CO16
21	3171	204	0.000		-108.73	-0.05	-0.37	0.10	-0.98	-0.05	CO16
21	2514		0.709	V_y	-29.65	3.60	-1.23	-0.61	-0.24	0.05	CO16
21	759		0.499		-28.89	-3.88	0.76	0.85	-0.40	-0.14	CO16
21	689	558	0.000	V_z	-40.78	0.47	6.13	0.88	-2.44	0.18	CO16
21	3174	215	0.000		-7.50	-1.04	-5.57	-0.55	0.91	-0.46	CO16
21	1889	756	1.174	M_T	-54.43	-3.77	1.11	2.25	0.05	2.70	CO16
21	3092	774	0.000		-50.33	-1.80	-0.73	-2.26	1.34	-1.38	CO16
21	689	161	1.077	M_y	-40.78	0.47	5.81	0.88	4.01	-0.32	CO16
21	3174	207	1.077		-7.51	-1.04	-5.26	-0.55	-4.92	0.65	CO16
22	2703	518	3.292	M_z	39.35	-1.80	1.45	-0.07	0.98	3.01	CO16
22	2719	627	0.000		34.73	-1.83	-1.05	-0.05	0.35	-3.03	CO16
	ULS CO1 - 1.35 * LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	84.47	-0.02	0.28	-0.21	0.33	-0.19	
21	3171	204	0.000		-146.99	-0.07	-0.54	0.13	-1.31	-0.08	
21	2514		0.709	V_y	-40.04	4.88	-1.67	-0.83	-0.33	0.07	
21	759		0.514		-38.99	-5.25	1.02	1.16	-0.53	-0.11	
21	689	558	0.000	V_z	-55.32	0.64	8.31	1.18	-3.31	0.25	
21	3174	215	0.000		-10.26	-1.42	-7.54	-0.75	1.22	-0.63	
21	1889	756	1.174	M_T	-73.76	-5.09	1.53	3.06	0.08	3.67	
21	3092	774	0.000		-68.25	-2.44	-0.97	-3.07	1.81	-1.88	
21	689	161	1.077	M_y	-55.32	0.65	7.87	1.18	5.44	-0.45	
21	3174	207	1.077		-10.28	-1.41	-7.11	-0.76	-6.67	0.90	
22	2703	518	3.292	M_z	53.11	-2.44	1.96	-0.10	1.32	4.07	
22	2719	627	0.000		46.88	-2.48	-1.42	-0.07	0.47	-4.09	
	ULS CO2 - 1.50 * LC1 + 1.35 * LC3										
	Total max/min values with corresponding values										
22	1580	873	0.000	N	191.25	-1.74	1.09	-0.01	-0.37	-3.02	
21	2890	880	2.189		-325.91	1.35	1.52	-0.25	3.15	-1.04	
22	2190	879	3.368	V_y	116.16	7.89	-0.93	0.17	0.07	-10.96	
22	1595	882	0.000		76.29	-8.42	0.01	0.09	1.54	-14.35	
21	719	564	0.000	V_z	-72.36	1.94	10.60	1.48	-4.27	0.77	
21	3004	190	0.000		-7.86	-2.61	-9.87	-1.10	1.52	-1.06	
21	1919	768	1.174	M_T	-101.01	-6.18	1.35	3.88	-0.32	4.32	
21	3013	766	0.000		-85.02	-2.84	-0.95	-3.86	2.23	-2.07	
21	714	186	1.077	M_y	-60.25	1.42	10.10	1.35	7.10	-1.05	
21	3004	182	1.077		-8.41	-1.92	-9.44	-1.12	-8.88	1.38	
22	2190	881	0.000	M_z	118.45	6.64	2.59	0.17	-2.68	13.14	

7.1 MEMBERS - INTERNAL FORCES BY SECTION — Static Analysis

Section No.	Member No.	Node No.	Location x [m]		Forces [kN] N	V_y	V_z	Moments [kNm] M_T	M_y	M_z	Member Comment Cor. Loading
22	1595	882	0.000	M_z	76.29	-8.42	0.01	0.09	1.54	-14.35	
	ULS CO3 - 1.50 * LC4 + 1.35 * LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	205.97	-0.09	0.47	-0.51	0.84	-0.49	
21	3140	169	0.000		-350.36	-0.13	-1.67	0.32	-3.03	-0.24	
21	2514		0.735	V_y	-96.23	11.89	-3.94	-2.01	-0.87	-0.14	
21	759		0.514		-93.22	-12.77	2.37	2.81	-1.26	-0.28	
21	689	558	0.000	V_z	-134.59	1.70	20.31	2.72	-8.05	0.63	
21	3040	170	0.000		-25.79	-3.55	-18.03	-1.95	2.69	-1.50	
21	1889	756	1.174	M_T	-178.32	-12.10	3.98	7.52	0.33	8.87	
21	3092	774	0.000		-165.46	-5.87	-2.19	-7.53	4.36	-4.58	
21	689	161	1.077	M_y	-134.64	1.70	18.84	2.70	13.28	-1.24	
21	3090	202	1.077		-26.46	-3.48	-16.63	-1.99	-16.03	2.30	
22	2703	518	3.292	M_z	138.08	-6.48	3.69	-0.26	2.83	10.71	
22	2719	627	0.000		122.00	-6.56	-2.13	-0.18	0.36	-10.74	
	ULS CO4 - 1.50 * LC2 + 1.35 * LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	248.47	-0.13	0.51	-0.61	1.03	-0.60	
21	3140	169	0.000		-419.18	-0.14	-2.19	0.38	-3.58	-0.30	
21	2514		0.735	V_y	-115.04	14.29	-4.71	-2.42	-1.04	-0.17	
21	759		0.514		-111.27	-15.35	2.82	3.38	-1.51	-0.33	
21	689	558	0.000	V_z	-162.06	2.10	24.46	3.21	-9.68	0.78	
21	3040	170	0.000		-31.48	-4.32	-21.58	-2.40	3.12	-1.80	
21	1889	756	1.174	M_T	-214.21	-14.46	4.94	9.09	0.47	10.65	
21	3092	774	0.000		-199.04	-7.06	-2.56	-9.10	5.24	-5.52	
21	689	161	1.077	M_y	-162.13	2.10	22.59	3.19	16.01	-1.56	
21	3090	202	1.077		-32.32	-4.22	-19.83	-2.46	-19.25	2.81	
22	2703	518	3.292	M_z	166.36	-7.86	4.27	-0.31	3.33	12.94	
22	2719	627	0.000		147.03	-7.94	-2.36	-0.21	0.32	-12.98	
	ULS CO5 - 0.90 * LC1 + 1.50 * LC2 + 1.35 * LC3										
	Total max/min values with corresponding values										
22	2886	473	3.292	N	255.55	-3.18	4.72	1.14	3.38	6.84	
21	2997	189	0.000		-456.39	0.03	-2.40	0.41	-3.76	-0.28	
21	2567	191	1.077	V_y	-22.43	15.08	-11.82	-2.02	1.03	-8.34	
21	1919		0.587		-231.38	-15.61	5.46	9.55	-2.81	2.00	
21	719		0.023	V_z	-172.34	2.92	25.88	3.37	-9.65	1.03	
21	3004	190	0.000		-29.33	-5.09	-22.96	-2.66	3.23	-2.07	
21	1919	768	1.174	M_T	-231.32	-15.12	4.94	9.62	0.27	11.08	
21	3013	766	0.000		-210.95	-7.30	-2.45	-9.60	5.44	-5.65	
21	714	186	1.077	M_y	-165.35	2.62	23.93	3.25	17.06	-1.97	
21	3004	182	1.077		-29.82	-4.58	-21.22	-2.74	-20.63	3.15	
22	2703	518	3.292	M_z	209.71	-7.80	4.18	-0.52	3.33	13.30	
22	2811	617	0.000		233.94	-9.00	-2.50	-0.48	0.51	-13.92	
	ULS CO6 - 0.90 * LC4 + 1.50 * LC2 + 1.35 * LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	327.80	-0.23	0.53	-0.81	1.38	-0.81	
21	3140		0.643		-544.63	-0.23	-1.26	0.49	-6.06	-0.31	
21	2514		0.735	V_y	-149.00	18.71	-6.12	-3.17	-1.37	-0.22	
21	759		0.514		-143.73	-20.10	3.64	4.45	-1.98	-0.43	
21	689		0.070	V_z	-212.97	2.92	32.17	4.06	-10.43	0.85	
21	3040	170	0.000		-42.35	-5.79	-28.05	-3.28	3.84	-2.35	
21	1889	756	1.174	M_T	-280.29	-18.72	6.84	12.04	0.78	13.95	
21	3092	774	0.000		-261.14	-9.25	-3.14	-12.04	6.87	-7.27	
21	689	161	1.077	M_y	-213.12	2.89	29.47	4.03	21.11	-2.21	
21	3090	202	1.077		-43.53	-5.60	-25.62	-3.39	-25.18	3.82	
22	2703	518	3.292	M_z	217.21	-10.39	5.31	-0.40	4.24	16.99	
22	2719	627	0.000		192.08	-10.47	-2.77	-0.28	0.25	-17.02	
	S Ch CO7 - LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	62.18	-0.01	0.21	-0.15	0.24	-0.14	
21	3171	204	0.000		-108.73	-0.05	-0.37	0.10	-0.98	-0.05	
21	2514		0.709	V_y	-29.65	3.60	-1.23	-0.61	-0.24	0.05	
21	759		0.499		-28.89	-3.88	0.76	0.85	-0.40	-0.14	
21	689	558	0.000	V_z	-40.78	0.47	6.13	0.88	-2.44	0.18	
21	3174	215	0.000		-7.50	-1.04	-5.57	-0.55	0.91	-0.46	
21	1889	756	1.174	M_T	-54.43	-3.77	1.11	2.25	0.05	2.70	
21	3092	774	0.000		-50.33	-1.80	-0.73	-2.26	1.34	-1.38	
21	689	161	1.077	M_y	-40.78	0.47	5.81	0.88	4.01	-0.32	

7.1 MEMBERS - INTERNAL FORCES BY SECTION

Static Analysis

Section No.	Member No.	Node No.	Location x [m]		N [kN]	Vy [kN]	Vz [kN]	MT [kNm]	My [kNm]	Mz [kNm]	Member Comment Cor. Loading
21	3174	207	1.077	My	-7.51	-1.04	-5.26	-0.55	-4.92	0.65	
22	2703	518	3.292	Mz	39.35	-1.80	1.45	-0.07	0.98	3.01	
22	2719	627	0.000		34.73	-1.83	-1.05	-0.05	0.35	-3.03	
	S Ch CO8 - LC1 + LC3										
	Total max/min values with corresponding values										
22	1580	873	0.000	N	130.95	-1.14	0.84	-0.01	-0.30	-2.04	
21	2890	880	2.189		-222.34	0.86	1.14	-0.17	2.14	-0.64	
22	2190	879	3.368	Vy	80.99	5.23	-0.73	0.12	0.02	-7.24	
22	1595	882	0.000		55.16	-5.61	0.12	0.06	0.97	-9.66	
21	719	564	0.000	Vz	-51.96	1.33	7.64	1.08	-3.08	0.53	
21	3004	190	0.000		-5.80	-1.83	-7.13	-0.77	1.13	-0.75	
21	1919	768	1.174	MT	-72.42	-4.49	0.97	2.79	-0.22	3.14	
21	3013	766	0.000		-61.35	-2.06	-0.72	-2.78	1.61	-1.51	
21	714	186	1.077	My	-43.93	0.98	7.29	1.00	5.10	-0.71	
21	3004	182	1.077		-6.16	-1.37	-6.81	-0.78	-6.38	0.97	
22	2190	881	0.000	Mz	82.52	4.38	1.87	0.12	-1.88	8.76	
22	1595	882	0.000		55.16	-5.61	0.12	0.06	0.97	-9.66	
	S Ch CO9 - LC4 + LC3										
	Total max/min values with corresponding values										
22	2886	620	0.000	N	141.69	-1.68	-1.36	0.74	-0.21	-1.15	
21	3140	169	0.000		-243.36	-0.10	-0.98	0.22	-2.16	-0.15	
21	2514		0.735	Vy	-67.02	8.20	-2.73	-1.39	-0.59	-0.10	
21	759		0.514		-65.05	-8.81	1.65	1.93	-0.86	-0.20	
21	689	558	0.000	Vz	-92.58	1.11	13.98	1.93	-5.55	0.42	
21	3040	170	0.000		-17.37	-2.40	-12.53	-1.29	1.95	-1.04	
21	1889	756	1.174	MT	-123.11	-8.43	2.60	5.14	0.16	6.12	
21	3092	774	0.000		-113.96	-4.05	-1.59	-5.15	3.01	-3.14	
21	689	161	1.077	My	-92.60	1.11	13.03	1.92	9.11	-0.79	
21	3090	202	1.077		-17.80	-2.37	-11.59	-1.31	-11.07	1.53	
22	2703	518	3.292	Mz	96.04	-4.47	2.60	-0.18	1.98	7.42	
22	2719	627	0.000		84.81	-4.53	-1.53	-0.12	0.28	-7.45	
	S Ch CO10 - LC2 + LC3										
	Total max/min values with corresponding values										
22	2886	620	0.000	N	169.72	-2.00	-1.48	0.89	-0.33	-1.35	
21	3140	169	0.000		-288.63	-0.12	-1.25	0.26	-2.54	-0.18	
21	2514		0.735	Vy	-79.51	9.76	-3.23	-1.65	-0.71	-0.12	
21	759		0.514		-77.10	-10.49	1.95	2.30	-1.03	-0.23	
21	689	558	0.000	Vz	-110.28	1.35	16.65	2.27	-6.61	0.51	
21	3040	170	0.000		-20.89	-2.88	-14.86	-1.56	2.27	-1.23	
21	1889	756	1.174	MT	-146.42	-9.99	3.16	6.14	0.23	7.28	
21	3092	774	0.000		-135.65	-4.82	-1.86	-6.15	3.58	-3.74	
21	689	161	1.077	My	-110.31	1.35	15.48	2.26	10.86	-0.97	
21	3090	202	1.077		-21.42	-2.83	-13.71	-1.59	-13.15	1.85	
22	2703	518	3.292	Mz	114.92	-5.37	2.98	-0.21	2.32	8.89	
22	2719	627	0.000		101.51	-5.44	-1.68	-0.15	0.25	-8.93	
	S Ch CO11 - 0.60 * LC1 + LC2 + LC3										
	Total max/min values with corresponding values										
22	2886	473	3.292	N	175.77	-2.17	3.30	0.78	2.36	4.74	
21	2997	189	0.000		-313.12	-0.01	-1.35	0.28	-2.67	-0.16	
21	2567	191	1.077	Vy	-14.69	10.27	-8.17	-1.34	0.57	-5.71	
21	1924		0.625		-160.56	-10.60	3.44	6.37	-1.74	1.74	
21	719	564	0.000	Vz	-116.81	1.89	17.56	2.38	-6.98	0.72	
21	3004	190	0.000		-19.31	-3.38	-15.78	-1.72	2.36	-1.41	
21	1919	768	1.174	MT	-157.46	-10.42	3.13	6.47	0.08	7.55	
21	3013	766	0.000		-143.25	-4.97	-1.81	-6.47	3.71	-3.82	
21	714	186	1.077	My	-112.19	1.69	16.35	2.31	11.52	-1.24	
21	3004	182	1.077		-19.60	-3.06	-14.63	-1.76	-14.05	2.06	
22	2703	518	3.292	Mz	143.82	-5.31	2.93	-0.35	2.32	9.12	
22	2811	617	0.000		160.14	-6.11	-1.79	-0.33	0.39	-9.54	
	S Ch CO12 - 0.60 * LC4 + LC2 + LC3										
	Total max/min values with corresponding values										
22	2886	620	0.000	N	220.30	-2.55	-1.69	1.16	-0.56	-1.67	
21	3140	169	0.000		-370.68	-0.13	-1.80	0.33	-3.20	-0.26	
21	2514		0.735	Vy	-102.04	12.61	-4.15	-2.13	-0.91	-0.15	
21	759		0.514		-98.78	-13.55	2.49	2.98	-1.33	-0.30	
21	689	558	0.000	Vz	-142.72	1.81	21.56	2.87	-8.54	0.67	
21	3040	170	0.000		-27.48	-3.78	-19.09	-2.08	2.82	-1.59	
21	1889	756	1.174	MT	-188.97	-12.81	4.24	7.98	0.36	9.40	

7.1 MEMBERS - INTERNAL FORCES BY SECTION

Static Analysis

Section No.	Member No.	Node No.	Location x [m]		Forces [kN] N	Vy	Vz	Moments [kNm] MT	My	Mz	Member Comment Cor. Loading
21	3092	774	0.000	M_T	-175.36	-6.22	-2.32	-7.99	4.62	-4.85	
21	689	161	1.077	M_y	-142.77	1.81	19.93	2.85	14.08	-1.33	
21	3090	202	1.077		-28.21	-3.69	-17.54	-2.13	-16.96	2.44	
22	2703	518	3.292	M_z	148.87	-7.01	3.68	-0.28	2.92	11.56	
22	2719	627	0.000		131.55	-7.09	-1.96	-0.19	0.21	-11.60	
	S Fr CO13 - LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	62.18	-0.01	0.21	-0.15	0.24	-0.14	
21	3171	204	0.000		-108.73	-0.05	-0.37	0.10	-0.98	-0.05	
21	2514		0.709	V_y	-29.65	3.60	-1.23	-0.61	-0.24	0.05	
21	759		0.499		-28.89	-3.88	0.76	0.85	-0.40	-0.14	
21	689	558	0.000	V_z	-40.78	0.47	6.13	0.88	-2.44	0.18	
21	3174	215	0.000		-7.50	-1.04	-5.57	-0.55	0.91	-0.46	
21	1889	756	1.174	M_T	-54.43	-3.77	1.11	2.25	0.05	2.70	
21	3092	774	0.000		-50.33	-1.80	-0.73	-2.26	1.34	-1.38	
21	689	161	1.077	M_y	-40.78	0.47	5.81	0.88	4.01	-0.32	
21	3174	207	1.077		-7.51	-1.04	-5.26	-0.55	-4.92	0.65	
22	2703	518	3.292	M_z	39.35	-1.80	1.45	-0.07	0.98	3.01	
22	2719	627	0.000		34.73	-1.83	-1.05	-0.05	0.35	-3.03	
	S Fr CO14 - 0.20 * LC1 + LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	62.85	-0.07	0.20	-0.15	0.24	-0.17	
21	2997	189	0.000		-116.76	-0.02	-0.39	0.10	-1.03	-0.05	
21	2320	196	1.077	V_y	-6.01	3.79	-2.99	-0.46	0.12	-2.12	
21	1924		0.881		-58.98	-3.91	1.13	2.33	-0.33	1.64	
21	719	564	0.000	V_z	-42.78	0.64	6.42	0.92	-2.56	0.25	
21	3004	190	0.000		-6.84	-1.20	-5.88	-0.59	0.95	-0.52	
21	1919	768	1.174	M_T	-57.92	-3.91	1.08	2.35	0.00	2.79	
21	3013	766	0.000		-52.69	-1.85	-0.72	-2.35	1.38	-1.40	
21	714	186	1.077	M_y	-41.25	0.58	6.09	0.90	4.22	-0.40	
21	3004	182	1.077		-6.92	-1.10	-5.56	-0.59	-5.21	0.72	
22	2703	518	3.292	M_z	48.99	-1.77	1.43	-0.12	0.98	3.09	
22	2811	617	0.000		54.32	-2.03	-1.09	-0.11	0.40	-3.21	
	S Fr CO15 - 0.20 * LC4 + LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	77.70	-0.01	0.25	-0.19	0.31	-0.18	
21	3171	204	0.000		-135.52	-0.06	-0.47	0.12	-1.22	-0.07	
21	2514		0.709	V_y	-37.11	4.51	-1.53	-0.77	-0.30	0.07	
21	759		0.514		-36.12	-4.85	0.94	1.07	-0.48	-0.11	
21	689	558	0.000	V_z	-50.99	0.59	7.68	1.09	-3.06	0.23	
21	3174	215	0.000		-9.46	-1.30	-6.96	-0.69	1.13	-0.58	
21	1889	756	1.174	M_T	-68.02	-4.70	1.39	2.82	0.06	3.38	
21	3092	774	0.000		-62.89	-2.24	-0.91	-2.82	1.67	-1.73	
21	689	161	1.077	M_y	-50.99	0.59	7.24	1.09	5.01	-0.41	
21	3174	207	1.077		-9.48	-1.30	-6.53	-0.69	-6.14	0.82	
22	2703	518	3.292	M_z	50.69	-2.33	1.68	-0.09	1.18	3.89	
22	2719	627	0.000		44.75	-2.37	-1.15	-0.07	0.33	-3.91	
	S Qp CO16 - LC3										
	Total max/min values with corresponding values										
21	230	231	0.000	N	62.18	-0.01	0.21	-0.15	0.24	-0.14	
21	3171	204	0.000		-108.73	-0.05	-0.37	0.10	-0.98	-0.05	
21	2514		0.709	V_y	-29.65	3.60	-1.23	-0.61	-0.24	0.05	
21	759		0.499		-28.89	-3.88	0.76	0.85	-0.40	-0.14	
21	689	558	0.000	V_z	-40.78	0.47	6.13	0.88	-2.44	0.18	
21	3174	215	0.000		-7.50	-1.04	-5.57	-0.55	0.91	-0.46	
21	1889	756	1.174	M_T	-54.43	-3.77	1.11	2.25	0.05	2.70	
21	3092	774	0.000		-50.33	-1.80	-0.73	-2.26	1.34	-1.38	
21	689	161	1.077	M_y	-40.78	0.47	5.81	0.88	4.01	-0.32	
21	3174	207	1.077		-7.51	-1.04	-5.26	-0.55	-4.92	0.65	
22	2703	518	3.292	M_z	39.35	-1.80	1.45	-0.07	0.98	3.01	
22	2719	627	0.000		34.73	-1.83	-1.05	-0.05	0.35	-3.03	

8 Stress Analysis

8.1

OBJECTS TO ANALYZE - STRESSES

	Object Type	Analyze All	Objects to Analyze Selected	To Analyze	Removed	Not Valid / Deact.	Comment
	Members	☒	1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,1601-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3422	1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,1601-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3422			
	Surfaces	☒	1-21,23-25,27-152,155-160,162-752,755-784,786-811,814-858,860,864-878,881-1758,1762,1763,1766-1788,1790-1801,1806-1819			1-21,23-25,27-152,155-160,162-752,755-784,786-811,814-858,860,864-878,881-1758,1762,1763,1766-1788,1790-1801,1806-1819	

8.2

OBJECTS TO ANALYZE - STRESS RANGES

	Object Type	Analyze All	Objects to Analyze Selected	To Analyze	Removed	Not Valid / Deact.	Comment
	Members	☐					
	Surfaces	☐					

8.3

DESIGN SITUATIONS

DS No.	Name	To Analyze	Active	Combinations to Design for Enumeration Method
1	ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒	☒	All
2	SLS - Characteristic	☒	☒	All
3	SLS - Frequent	☒	☒	All
4	SLS - Quasi-permanent	☒	☒	All

8.4

MATERIALS

Legend
⚙ Concrete Settings

Material No.	Name	To Analyze	Material Type	Options	Comment
3	S355M	☒	Steel		
4	S355N	☒	Steel		
5	C30/37	☒	Concrete	⚙	
6	C35/45	☒	Concrete	⚙	
7	C35/45	☒	Concrete	⚙	
8	S355N	☒	Steel		

8.5

SURFACE CONFIGURATIONS

Conf. No.	Name	Assigned to Surfaces	Surface Sets	Comment
1	Default	All	All	

8.5.1 SURFACE CONFIGURATIONS - STRAINS TO CALCULATE

Conf. No.	Enabled	Strain Type	Limit Strain [‰]
1	Default		

8.6 SOLID CONFIGURATIONS

Conf. No.	Name	Assigned to Solids	Assigned to Solid Sets	Comment
1	Default	All	All	

8.6.1 SOLID CONFIGURATIONS - STRAINS TO CALCULATE

Conf. No.	Enabled	Strain Type	Limit Strain [‰]
1	Default		

8.7.1 NOT VALID / DEACTIVATED

Stress-Strain Analysis

	Objects Type	Objects No.	Error Code	Description
	Surface	1-21,23-25,27-152,155-160,162-752,755-784,786-811,814-858,860,864-878,881-1758,1762,1763,1766-1788,1790-1801,1806-1819	ER0001	Deactivated for calculation
	Surface	1-21,23-25,27-152,155-160,162-752,755-784,786-811,814-858,860,864-878,881-1758,1762,1763,1766-1788,1790-1801,1806-1819	ER0017	Stiffness type is not designable.

8.7.2 STRESSES ON MEMBERS BY DESIGN SITUATION

Stress-Strain Analysis

Design Situation	Member No.	Location x [m]	Stress Point No.	Loading No.	Stress Type	Stress [N/mm²] Existing	Stress [N/mm²] Limit	Stress Ratio η [--]
	ULS (STR/GEO) - Permanent and transient - Eq. 6.10							
DS1	739	1.077	36	CO6	$\sigma_{x,tot}$	-331.933	355.000	0.935 ✓
	1889	0.757	17	CO6	τ_{tot}	89.876	204.959	0.439 ✓
	3138	0.000	36	CO6	$\sigma_{eqv,von Mises}$	337.643	355.000	0.951 ✓
	SLS - Characteristic							
DS2	739	1.077	36	CO12	$\sigma_{x,tot}$	-221.262	355.000	0.623 ✓
	1889	0.679	17	CO12	τ_{tot}	59.769	204.959	0.292 ✓
	3138	0.000	36	CO12	$\sigma_{eqv,von Mises}$	229.548	355.000	0.647 ✓
	SLS - Frequent							
DS3	3138	0.000	36	CO15	$\sigma_{x,tot}$	80.535	355.000	0.227 ✓
	1889	0.388	17	CO15	τ_{tot}	21.179	204.959	0.103 ✓
	3138	0.000	36	CO15	$\sigma_{eqv,von Mises}$	83.626	355.000	0.236 ✓
	SLS - Quasi-permanent							
DS4	3169	0.000	36	CO16	$\sigma_{x,tot}$	64.559	355.000	0.182 ✓
	1889	0.312	17	CO16	τ_{tot}	16.926	204.959	0.083 ✓
	3169	0.000	36	CO16	$\sigma_{eqv,von Mises}$	67.024	355.000	0.189 ✓

9 Steel Design

9.1 OBJECTS TO DESIGN

	Object Type	Design All	Objects to Design Selected	Objects to Design To Calculate	Removed	Not Valid / Deact.	Comment
	Members	☒	1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,160	1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,160			

9.1 OBJECTS TO DESIGN

	Object Type	Design All	Objects to Design Selected	To Calculate	Removed	Not Valid / Deact.	Comment
			1-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3422	1-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3422			

9.2 DESIGN SITUATIONS

DS No.	EN 1990 | CEN | 2010-04 Design Situation Type	To Design	Active	EN 1993 | CEN | 2015-06 Design Situation Type	Combinations to Design for Enumeration Method
1	ULS ULS (STR/GEO) - Permanent and transient - Eq. 6.10	☒	☒	ULS ULS (STR/GEO) - Permanent and transient	All
2	S Ch SLS - Characteristic	☒	☒	S Ch SLS - Characteristic	All
3	S Fr SLS - Frequent	☒	☒	S Fr SLS - Frequent	All
4	S Qp SLS - Quasi-permanent	☒	☒	S Qp SLS - Quasi-permanent	All

9.3 MATERIALS

Legend
Concrete Settings

Material No.	Name	To Design	Material Type	Options	Comment
3	S355M	☒	Steel		
4	S355N	☒	Steel		
5	C30/37	☒	Concrete	⚙	
6	C35/45	☒	Concrete	⚙	
7	C35/45	☒	Concrete	⚙	
8	S355N	☒	Steel		

9.4 SECTIONS

Legend
Thin-walled model
Warping stiffness deactivated

Section No.	Name	Material	To Design	Section Type	Use Other Section for Design	Section Classification	Options
1	HEM 1000	2	☒	Standardized - Steel	--	Automatically	
2	CIRULAR STRUCTURE 2#	??	☒	Basic	--	Class 3	
3	CHC 508.0x10.0	4	☒	Standardized - Steel	--	Automatically	
4	IPE 80	1	☒	Standardized - Steel	--	Automatically	
5	Celsius 355 CHS 76.1x6.3	4	☒	Standardized - Steel	--	Automatically	
6	Celsius 355 CHS 114.3x8	3	☒	Standardized - Steel	--	Automatically	
7	Celsius 355 CHS 193.7x12.5	3	☒	Standardized - Steel	--	Automatically	
8	R_M1 600/300	7	☒	Parametric - Massive I	--	Class 3	
9	Celsius 355 RHS 120x60x8.8	3	☒	Standardized - Steel	--	Automatically	
10	Celsius 355 RHS 120x60x8.8	3	☒	Standardized - Steel	--	Automatically	
11	Celsius 355 RHS 150x100x6.3	3	☒	Standardized - Steel	--	Automatically	
12	Celsius 355 RHS 150x100x10	3	☒	Standardized - Steel	--	Automatically	
13	Celsius 355 RHS 150x100x10	3	☒	Standardized - Steel	--	Automatically	
14	Celsius 355 RHS 200x100x14.2	3	☒	Standardized - Steel	--	Automatically	
15	Celsius 355 RHS 120x80x8.8	3	☒	Standardized - Steel	--	Automatically	
16	Celsius 355 RHS 150x100x8	3	☒	Standardized - Steel	--	Automatically	

9.4 SECTIONS

Section No.	Name	Material	To Design	Section Type	Use Other Section for Design	Section Classification	Options
17	Celsius 355 RHS 150x100x8.8	3	☒	Standardized - Steel	--	Automatically	
18	R_M1 250/500	6	☒	Parametric - Massive I	--	Class 3	
19	R_M1 250/500	6	☒	Parametric - Massive I	--	Class 3	
20	Celsius 355 RHS 150x100x5	3	☒	Standardized - Steel	--	Automatically	
21	CHS 139.7x6.3	3	☒	Standardized - Steel	--	Automatically	
22	Celsius 355 CHS 193.7x16	3	☒	Standardized - Steel	--	Automatically	

9.5 ULTIMATE CONFIGURATIONS

Config. No.	Name	Assigned to Members	Assigned to Member Sets	Comment
1	Default	All	All	

9.5.1 ULTIMATE CONFIGURATIONS - SETTINGS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	General			
	☒ Perform stability design			
	Limit Values for Special Cases			
	Tension ($N_{t,Ed}$ / $N_{t,Rd}$)	η_{Nt}	0.001	--
	Compression ($N_{c,Ed}$ / $N_{pl,Rd}$)	η_{Nc}	0.001	--
	Shear ($V_{y,Ed}$ / $V_{pl,y,Rd}$)	η_{Vy}	0.001	--
	Shear ($V_{z,Ed}$ / $V_{pl,z,Rd}$)	η_{Vz}	0.001	--
	Shear stress due to torsion ($\tau_{t,Ed}$ / τ_{Rd})	$\eta_{\tau t}$	0.010	--
	Bending about major axis ($M_{y,Ed}$ / $M_{pl,y,Rd}$)	η_{My}	0.001	--
	Bending about minor axis ($M_{z,Ed}$ / $M_{pl,z,Rd}$)	η_{Mz}	0.001	--
	Thin-Walled Analysis			
	Maximum number of iterations	n_{max}	3	
	Maximum difference between iterations	δ_{max}	1.00	%
	☐ Neglect bending moments due to the shift of the centroid			
	☐ Consider effective widths according to EN 1993-1-5, Annex E			
	Options			
	Elastic design			
	☐ Elastic design (also for class 1 and class 2 sections)			
	☐ Use verification acc. to equation 6.1 for elastic design			
	Plastic design			
	☐ Use linear interaction acc. to 6.2.1(7) for section check for M+N			
	Design of Cold-Formed Sections Acc. to EN 1993-1-3			
	☒ Perform design of cold-formed sections			
	Forming factor k acc. to 3.2.2(3)		Roll forming (k = 7)	
	☐ Use elastic design acc. to 6.1.6			
	☐ Consider web as stiffened acc. to Tab. 6.1			
	Limiting inclination of principal axes acc. to 6.2.4(2)	α_{lim}	0.00	deg
	Design of Shear Buckling Acc. to EN 1993-1-5			
	☐ Perform design of shear buckling			
	Stability Analyses with Second-Order Internal Forces			
	☐ Use γ_{M1} for determination of the section resistance			
	Settings for Stability Design			
	Calculation Method			
	Equivalent member method (effective lengths)			
	Structure Type acc. to Table B.3			
	☐ Sway y-y (C_{my} = 0.9)			
	☐ Sway z-z (C_{mz} = 0.9)			
	2D - General method (4 degrees of freedom)			
	☒ Enable also for non-I-sections			
	☐ Extension methods			

9.5.1

ULTIMATE CONFIGURATIONS - SETTINGS

Config. No.	Description	Symbol	Value	Unit
	Include Second-Order Effects Acc. to 5.2.2(4) by Increasing Bending Moment About			
	☐ Major y-axis			
	☐ Minor z-axis			
	Position of Positive Transverse Load Application			
	Vertical position			
	◉ On profile edge (destabilizing effect)			
	○ At shear point			
	○ At center point			
	○ On profile edge (stabilizing effect)			
	Parameters for Lateral-Torsional Buckling			
	6.3.2.3 Determine lateral-torsional buckling curves for 6.3.2 and 6.3.3			
	○ Always according to Eq. 6.56 General case (conservative)			
	◉ If possible, according to Eq. 6.57, otherwise according to Eq. 6.56			
	☒ Use factor f for modification of χ_{LT} acc. to 6.3.2.3(2)			
	6.3.3(4) Parameters k_{yy}, k_{yz}, k_{zy}, k_{zz}			
	Determine interaction factors for 6.3.3(4) according to			
	○ Method 1 acc. to Annex A			
	◉ Method 2 acc. to Annex B			
	Lateral-Torsional Buckling of Hollow Sections			
	☒ Perform design for non-circular doubly symmetric hollow sections			
	Stability Design of Cold-Formed Sections Acc. to EN 1993-1-3			
	☒ Design of bending with axial force acc. to 6.2.5(2) or 6.3			

9.6

SERVICEABILITY CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Comment
1	Default	All	All	

9.6.1

SERVICEABILITY CONFIGURATIONS - SETTINGS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Serviceability Limits (Deflections) Acc. to 7.2			
	Beam limits - action combination (Table A 1.4 of EN 1990)			
	Characteristic	L /	300	--
	Frequent	L /	200	--
	Quasi-permanent	L /	200	--
	Cantilever limits - action combination (Table A 1.4 of EN 1990)			
	Characteristic	L_c /	150	--
	Frequent	L_c /	100	--
	Quasi-permanent	L_c /	100	--
	Vibration Design			
	Vibration design	$w_{inst,lim}$	5.0	mm
	Limitation of Web Breathing			
	☐ Design as steel bridge structure acc. to EN 1993-2, 7.4			

9.7

FIRE RESISTANCE CONFIGURATIONS

Config. No.	Name	Assigned to Members	Member Sets	Comment
1	Default	All	All	

9.7.1

FIRE RESISTANCE CONFIGURATIONS - SETTINGS

Config. No.	Description	Symbol	Value	Unit
1	Default			
	Definition of Temperature			
	Define final temperature		Analytically	
	Fire design settings			

9.7.1 FIRE RESISTANCE CONFIGURATIONS - SETTINGS

Config. No.	Description	Symbol	Value	Unit
	Required time of fire resistance	$t_{fi,req}$	15	min
	Fire exposure		All Sides	
	Time interval of analysis	Δt	5.000	s
	Fire protection			
	☐ Set fire protection parameters			
	Temperature curve for determination of temperature of gases			
	Temperature curve			
	◉ Standard temperature-time curve			
	○ External fire curve			
	○ Hydrocarbon curve			
	Coefficient of heat transfer by convection	α_c	25	$W \cdot m^{-2} \cdot K^{-1}$
	Thermal actions for temperature analysis			
	Configuration factor	φ	1.000	--
	☐ Galvanized surface of carbon steel member			
	Surface emissivity of carbon steel member	ε_m	0.700	--
	Surface emissivity of stainless steel member	ε_m	0.400	--
	Emissivity of fire	ε_f	1.000	--

9.8.1 DESIGN RATIOS ON MEMBERS BY DESIGN SITUATION

Steel Design

Design Situation	Member No.	Location x [m]	Stress Point No.	Loading No.	Design Check Ratio η [--]	Type	Description
	ULS (STR/GEO) - Permanent and transient - Eq. 6.10						
DS1	1	0.236		CO2	0.000	SP0100.00	Section Proof | Negligible internal forces
	230	2.170		CO6	0.350	SP1100.00	Section Proof | Tension acc. to EN 1993-1-1, 6.2.3
	3140	0.762		CO6	0.581	SP1200.00	Section Proof | Compression acc. to EN 1993-1-1, 6.2.4
	1889	1.174	1	CO6	0.365	SP2100.00	Section Proof | Torsion acc. to EN 1993-1-1, 6.2.7
	2619	0.000		CO6	0.027	SP3100.01	Section Proof | Shear in z-axis and torsion acc. to EN 1993-1-1, 6.2.7(9) | Plastic design
	364	1.534		CO6	0.021	SP3100.02	Section Proof | Shear in z-axis acc. to EN 1993-1-1, 6.2.6(2) | Plastic design
	3106	0.735		CO6	0.059	SP3200.01	Section Proof | Shear in y-axis and torsion acc. to EN 1993-1-1, 6.2.7(9) | Plastic design
	2293	0.208		CO6	0.030	SP3200.02	Section Proof | Shear in y-axis acc. to EN 1993-1-1, 6.2.6(2) | Plastic design
	689	0.070		CO6	0.107	SP3300.01	Section Proof | Resulting shear and torsion acc. to EN 1993-1-1, 6.2.7(9) | Plastic design
	2540	1.407		CO6	0.034	SP3300.02	Section Proof | Resulting shear acc. to EN 1993-1-1, 6.2.6(2) | Plastic design
	3090	1.077		CO6	0.633	SP4100.03	Section Proof | Bending about y-axis acc. to EN 1993-1-1, 6.2.5 | Plastic design
	759	1.286		CO6	0.376	SP5100.03	Section Proof | Bending about z-axis acc. to EN 1993-1-1, 6.2.5 | Plastic design
	3138	0.000	36	CO6	0.951	SP6100.00	Section Proof | Axial and shear stress acc. to EN 1993-1-1, 6.2.1(5) | Elastic design
	3067	1.077		CO6	0.416	SP6500.01	Section Proof | Biaxial bending, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	3140	1.500		CO6	0.539	SP6500.02	Section Proof | Bending about y-axis, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	1929	1.066		CO6	0.429	SP6500.03	Section Proof | Bending about z-axis, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	189	0.000		CO5	0.155	SP6500.04	Section Proof | Biaxial bending and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	3140	0.762		CO6	0.624	ST1100.00	Stability | Flexural buckling about principal y-axis acc. to EN 1993-1-1, 6.3.1
				CO6	0.624	ST1300.00	Stability | Flexural buckling about principal z-axis acc. to EN 1993-1-1, 6.3.1
	2238	0.000		CO1	0.000	ST2100.00	Stability | Lateral torsional buckling acc. to EN 1993-1-1, 6.3.2
	3140	0.762		CO6	0.811	ST3100.00	Stability | Bending and buckling about principal axes acc. to EN 1993-1-1, 6.3.3
	151	0.000		CO1	Warning ⚠	WA5001.00	Warning | Torsion is neglected for stability design checks
	SLS - Characteristic						
DS2	1	0.000		CO7	0.000	SE0100.00	Serviceability | Negligible deflections
	685	0.974		CO12	0.319	SE1100.00	Serviceability | Deflections in z-direction
	2956	0.840		CO12	0.124	SE1200.00	Serviceability | Deflections in y-direction
	SLS - Frequent						
DS3	1	0.000		CO13	0.000	SE0100.00	Serviceability | Negligible deflections
	1234	0.500		CO15	0.076	SE1100.00	Serviceability | Deflections in z-direction
	2956	0.840		CO15	0.029	SE1200.00	Serviceability | Deflections in y-direction
	SLS - Quasi-permanent						
DS4	1	0.000		CO16	0.000	SE0100.00	Serviceability | Negligible deflections
	1234	0.500		CO16	0.061	SE1100.00	Serviceability | Deflections in z-direction
	3031	0.840		CO16	0.023	SE1200.00	Serviceability | Deflections in y-direction

10 Design Overview

10.1 DESIGN OVERVIEW

Design Overview

Addon	Objects Type	Objects No.	Location [m]	Design Situation	Loading No.	Design Check Ratio η [--]	Design Check Type	Description
Stress-Strain Analysis	Member	3138	x: 0.000	DS1	CO6	0.951 ✔	$\sigma_{eqv,von\ Mises}$	Equivalent stress (von Mises)
Stress-Strain Analysis	Member	739	x: 1.077	DS1	CO6	0.935 ✔	$\sigma_{x,tot}$	Total normal stress
Stress-Strain Analysis	Member	1889	x: 0.757	DS1	CO6	0.439 ✔	τ_{tot}	Total shear stress
Steel Design	Member	151-154,156-159,161-164,166-169,171-174,176-179,181-184,186-189,191-194,196-224,226,227,229,231,232,234,236,237,239,241,242,244,246,247,249,251,252,254,256,257,259,261,262,264,266,267,269,271,272,274,276,277,279,281,282,284,286,287,289,291,292,294,296,297,299,386,401,407,409,411,412,472,474,676-679,681-684,686-689,691-709,711-714,716-719,721-724,726-729,731-739,741-744,746-749,751,752,754,756,757,759,761,762,764,766,767,769,771,772,774,776,777,779,781,782,784,786,787,789,791,792,794,796,797,799,801,802,804,806,807,809,811,812,814,816,817,819,821,822,824,864,904,909,917,919,929,931,932,934,936,942,944,959,964,969,974,996,999,1205,1210,1215,1220,1225,1230,1235,1240,1245,1250,1255,1260,1265,1270,1275-1279,1281-1284,1286-1289,1291-1294,1296-1299,1301-1329,1331-1334,1336-1339,1341-1344,1346-1349,1351,1354,1356,1359,1361,1364,1366,1369,1371,1374,1376,1379,1381,1384,1386,1389,1391,1394,1396,1399,1401,1404,1406,1409,1411,1414,1416,1419,1421,1424,1524,1537,1562,1577,1582,1591,1592,1596,1599,1602,1604,1607,1612,1617,1622,1627,1632,16	x: 0.000	DS1	CO1	Warning ⚠	WA5001.00	Warning | Torsion is neglected for stability design checks

10.1 DESIGN OVERVIEW

	Addon	Objects Type	Objects No.	Location [m]	Design Situation	Loading No.	Design Check Ratio η [--]	Design Check Type	Description
			37,1642,1647,1803,1805,1808,1810,1813,1815,1818,1820,1823,1825,1828,1830,1833,1835,1838,1840,1843,1845,1848,1850,1853,1855,1858-1860,1863-1865,1868,1870,1873,1875-1877,1879,1881,1882,1884,1886,1887,1889,1891,1892,1894,1896,1897,1899,1901,1902,1904,1906,1907,1909,1911,1912,1914,1916,1917,1919,1921,1922,1924,1926,1927,1929,1931,1932,1934,1936,1937,1939,1941,1942,1944,1946,1947,1949,1952,1957,1962,1967,1972,1977,1982,1987,1992,1997,2002,2007,2012,2017,2022,2114,2131,2134,2139,2144,2156,2169,2176,2179,2184,2186,2189,2192,2194,2196,2197,2199,2201,2204,2206,2209,2211,2214,2216,2219,2221,2224,2226,2229,2231,2234,2236,2239,2241,2244,2246,2249,2252-2254,2261,2269,2277,2283,2284,2294,2300-2302,2308,2309,2311-2329,2331,2334,2340-2343,2351,2358,2371-2376,2379-2388,2390,2391,2401,2404,2415,2422,2423,2426-2433,2436-2443,2452,2453,2455-2458,2465,2467-2469,2478,2479,2494-2499,2511-2517,2519,2522,2525,2526,2528,2535,2537,2543-2555,2558-2568,2581,2598,2599,2601-2605,2607,2608,2641,2642,2675-2677,2697-2701,2715,2723,2726,2735,2741,2748,2758,2768,2776,2779,2784,2798,2810,2813,2817,2829,2836,2840,2846,2859,2864,2874-2876,2884,2889-2891,2898,2901,2903,2906,2908,2922,2925,2940,2943,295						

Matthew Rapa
W23 Compass Point | SWQ2323 Swieqi | Malta

10.1 DESIGN OVERVIEW

	Addon	Objects Type	Objects No.	Location [m]	Design Situation	Loading No.	Design Check Ratio η [--]	Design Check Type	Description
			1,2953,2954,2956,2958-2960,2964,2965,2967-2970,2972,2973,2975,2977,2983,2996-2999,3002-3004,3011-3016,3018,3019,3021,3022,3028,3030,3031,3035,3038-3044,3046-3048,3050-3056,3058,3060-3062,3064,3066-3069,3072,3073,3078,3080,3081,3084-3095,3098-3102,3105-3107,3110-3115,3118-3122,3124,3125,3127,3128,3140-3142,3146,3148-3154,3171,3172,3174,3176,3178,3179,3181,3182,3191,3192,3199-3202,3376,3399,3402,3409-3414						
	Steel Design	Member	3138	x: 0.000	DS1	CO6	0.951 ✓	SP6100.00	Section Proof | Axial and shear stress acc. to EN 1993-1-1, 6.2.1(5) | Elastic design
	Steel Design	Member	3140	x: 0.762	DS1	CO6	0.811 ✓	ST3100.00	Stability | Bending and buckling about principal axes acc. to EN 1993-1-1, 6.3.3
	Steel Design	Member	3090	x: 1.077	DS1	CO6	0.633 ✓	SP4100.03	Section Proof | Bending about y-axis acc. to EN 1993-1-1, 6.2.5 | Plastic design
	Steel Design	Member	3140	x: 0.762	DS1	CO6	0.624 ✓	ST1100.00	Stability | Flexural buckling about principal y-axis acc. to EN 1993-1-1, 6.3.1
	Steel Design	Member	3140	x: 0.762	DS1	CO6	0.624 ✓	ST1300.00	Stability | Flexural buckling about principal z-axis acc. to EN 1993-1-1, 6.3.1
	Steel Design	Member	3140	x: 0.762	DS1	CO6	0.581 ✓	SP1200.00	Section Proof | Compression acc. to EN 1993-1-1, 6.2.4
	Steel Design	Member	3140	x: 1.500	DS1	CO6	0.539 ✓	SP6500.02	Section Proof | Bending about y-axis, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	Steel Design	Member	1929	x: 1.066	DS1	CO6	0.429 ✓	SP6500.03	Section Proof | Bending about z-axis, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	Steel Design	Member	3067	x: 1.077	DS1	CO6	0.416 ✓	SP6500.01	Section Proof | Biaxial bending, axial force and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	Steel Design	Member	759	x: 1.286	DS1	CO6	0.376 ✓	SP5100.03	Section Proof | Bending about z-axis acc. to EN 1993-1-1, 6.2.5 | Plastic design
	Steel Design	Member	1889	x: 1.174	DS1	CO6	0.365 ✓	SP2100.00	Section Proof | Torsion acc. to EN 1993-1-1, 6.2.7
	Steel Design	Member	230	x: 2.170	DS1	CO6	0.350 ✓	SP1100.00	Section Proof | Tension acc. to EN 1993-1-1, 6.2.3
	Steel Design	Member	685	x: 0.974	DS2	CO12	0.319 ✓	SE1100.00	Serviceability | Deflections in z-direction
	Steel Design	Member	189	x: 0.000	DS1	CO5	0.155 ✓	SP6500.04	Section Proof | Biaxial bending and shear acc. to EN 1993-1-1, 6.2.9.1 and 6.2.10 | Plastic design
	Steel Design	Member	2956	x: 0.840	DS2	CO12	0.124 ✓	SE1200.00	Serviceability | Deflections in y-direction
	Steel Design	Member	689	x: 0.070	DS1	CO6	0.107 ✓	SP3300.01	Section Proof | Resulting shear and torsion acc. to EN 1993-1-1, 6.2.7(9) | Plastic design
	Steel Design	Member	3106	x: 0.735	DS1	CO6	0.059 ✓	SP3200.01	Section Proof | Shear in y-axis and torsion acc. to EN 1993-1-1, 6.2.7(9) | Plastic design
	Steel Design	Member	2540	x: 1.407	DS1	CO6	0.034 ✓	SP3300.02	Section Proof | Resulting shear acc. to

10.1 DESIGN OVERVIEW

Design Overview

	Addon	Objects Type	Objects No.	Location [m]	Design Situation	Loading No.	Design Check Ratio η [--]	Design Check Type	Description
									EN 1993-1-1, 6.2.6(2) | Plastic design
	Steel Design	Member	2293	x: 0.208	DS1	CO6	0.030 ✓	SP3200.02	Section Proof | Shear in y-axis acc. to EN 1993-1-1, 6.2.6(2) | Plastic design
	Steel Design	Member	2619	x: 0.000	DS1	CO6	0.027 ✓	SP3100.01	Section Proof | Shear in z-axis and torsion acc. to EN 1993-1-1, 6.2.7(9) | Plastic design
	Steel Design	Member	364	x: 1.534	DS1	CO6	0.021 ✓	SP3100.02	Section Proof | Shear in z-axis acc. to EN 1993-1-1, 6.2.6(2) | Plastic design
	Steel Design	Member	1,4,24,28,29,31,33,43,48,335,532,562,565,570,1051,1052,1054,1056,1057,1059,1061,1062,1064,1066,1067,1069,1071,1072,1074,1076,1077,1079,1081-1084,1086-1097,1099-1102,1104,1106,1107,1109,1111,1112,1114,1116,1117,1119,1121,1122,1124,1651,1652,1656,1657,1661,1662,1666,1667,1671,1672,1676-1678,1681-1683,1685-1687,1690-1699,1701,1702,1704,1706,1707,1709,1711,1712,1714,1716,1717,1721,1722,1724,2238,2588,2593,2596,2597,2652,2654,2660-2666,2670,2690,2692-2696,3268,3269,3273,3274,3281,3284,3285,3289,3290,3301,3302,3317,3318,3321,3322,3324,3329,3330,3333-3340,3342,3343,3345-3350,3363-3365	x: 0.236	DS1	CO2	0.000 ✓	SP0100.00	Section Proof | Negligible internal forces
	Steel Design	Member	2238	x: 0.000	DS1	CO1	0.000 ✓	ST2100.00	Stability | Lateral torsional buckling acc. to EN 1993-1-1, 6.3.2
	Steel Design	Member	1-405,407-412,415-510,512-936,941-1461,1463,1464,1466-1537,1540-1586,1588,1589,1591-1596,1598,1599,1601-2055,2057-2062,2064-2177,2179,2180,2182,2184-2187,2189,2190,2192,2194-2197,2199-2202,2204-2207,2209-2212,2214-2217,2219-2222,2224-2227,2229-2232,2234-2242,2244-2247,2249-2290,2293-2469,2471-2823,2825-2876,2878-2887,2889-2908,2910-2928,2930,2932-3365,3376,3377,3397-3399,3402,3407-3422	x: 0.000	DS2	CO7	0.000 ✓	SE0100.00	Serviceability | Negligible deflections

L-Università ta' Malta	**CVE 5010- Thesis Project**		
	Subject: Wind Load		
CALCULATION SHEET	**Made by:** Matthew Rapa	**Date:**	19/03/2025

EN 1991-1-4

WIND LOAD CALCULATION

Basic Wind Velocity

4.1 $$v_b = c_{dir} \cdot c_{season} \cdot v_{b,0}$$

Vb0	31	m/s
Cdir	1	
Cseason	1	
Vb	31	m/s

Terrain Roughness

4.5 $$k_r = 0{,}19 \cdot \left(\frac{z_0}{z_{0,II}}\right)^{0{,}07}$$

Zo	0.05	Terrain II
ZoII	0.05	
Zmin	2	
Kr	0.19	

4.4 $$c_r(z) = k_r \cdot \ln\left(\frac{z}{z_0}\right)$$

$$c_r(z) = c_r(z_{min})$$

Kr	0.19	
z	13.83	m
zo	0.05	
cr(z)	1.07	

Mean Wind Velocity

4.3 $$v_m(z) = c_r(z) \cdot c_o(z) \cdot v_b$$

co(z)	1.00	
vm(z)	33.12	m/s

Wind Turbulence

4.7

$$I_v(z) = \frac{\sigma_v}{v_m(z)} = \frac{k_I}{c_o(z) \cdot \ln(z/z_0)}$$

kI	1.00
co(z)	1
Iv(z)	0.1778545

4.6 **Standard Deviation of Turbulence**

$$\sigma_v = k_r \cdot v_b \cdot k_I$$

kI	1
σ_v	5.89

Basic Velocity Pressure

4.8

$$q_b = \tfrac{1}{2} \cdot \rho \cdot v_b^2$$

p	1.25	kg/m3
qb	0.601	kN/m2

$$q_p(z) = \left[1 + 7 \cdot I_v(z)\right] \cdot \tfrac{1}{2} \cdot \rho \cdot v_m^2(z) = c_e(z) \cdot q_b$$

qp(z)	1538.84	N/m2
qp(z)	1.5388402	kN/m2

Assuming a rectangular plan

h=	13.83	m
d=	32.22	m

CL 2.2.2. h/d 0.4292365

	A	B	C	D	E
$c_{pe,10}$	-1.2	-0.8	-0.5	0.8	-0.5
cpe,1	-1.4	-1.1	-0.5	1	-0.5

$$w_e = q_p(z_e) \cdot c_{pe}$$

External Wind Forces

$$F_{w,e} = c_s c_d \cdot \sum_{\text{surfaces}} w_e \cdot A_{ref}$$

Finding Cs

$$c_s = \frac{1+7 \cdot I_v(z_s) \cdot \sqrt{B^2}}{1+7 \cdot I_v(z_s)}$$

Where B	1
Iv(Zs)	0.1779
Cs	1

Finding Cd

$$c_d = \frac{1+2 \cdot k_p \cdot I_v(z_s) \cdot \sqrt{B^2 + R^2}}{1+7 \cdot I_v(z_s) \cdot \sqrt{B^2}}$$

Where R	1
Kp	3
Cd	1.1176687

z(m)	13.83	m
qp(h)	1538.84	N/m2
Area	445.60	m2
We,D	356.48	N/m2
We,E	769.4201	N/m2
Fw,e	56.073991	kN
Moment	775.50329	kNm
lever arm	32.22	m
Shear Force	56.073991	kN

L-Università ta' Malta	CVE 5010- Thesis Project	
	Subject: Calculations for Services	
CALCULATION SHEET	**Name:** Matthew Rapa	**Date:** 19/03/2025

WATER FLOW CALCULATION

Waterflow Cross-Section

Diameter of Circular roof	3.5	m
Circumference of circular roof	10.99557429	m2
Height of waterfall	10	m

Perimeter Area of water sheet

Assumed thickness	0.05	m

Perimeter Area

A=c*t

A	0.5497787	m2

Volume of Water Column

V = A * h	5.4977871	m3

Assumed Circulation Time =	15	mins
Desired Flow rate =	4	m3/min
Vflow = flow rate * Recirculation time =	60	m3
V TOTAL = V COLUMN + V FLOW =	65.4977871	m3
Water Required for singular water feature=	65.4977871	m3

Reservoir Size

Outdoor Garden

Amount of water /sqm/week	7.5	lt/m2/week
Outdoor Garden size	11000	m2
Amount of water needed	82500	lt/week

Indoor Garden

Amount of water/sqm/week	5	lt/m2/week
Indoor Garden Size	2400	m2
No. of Indoor Gardens	2.5	
Amount of water needed	75000	lt/week

Water Needed for Gardens	157500	lt/week
Water evaporation		
Total area for swamp feature	120	m2
Assume 2lt/m2 of evaporation	2	lt/m2/day
	7	days/week
	1680	lt/week
Assume 1.5 buffer	1.5	
Size of reservoir	238770	lt
	238.77	m3
Assuming reservoir height of	1.5	m
Area required	159.18	m2
Ventilation		
Floor Area	800	m2
Optimal Ventilaton	30	%
Area for Louvers	240	m2

L-Università ta' Malta	**CVE 5010- Thesis project**		
	Subject: Local Analysis of Structure		
CALCULATION SHEET	**Name:** Matthew Rapa	**Date:**	19/03/2025

Section Properties EN 10210-2: 2006-04 TATA STEEL	**SECTION PROPERTIES**		
	Section CHS 139.7x6.3		
	Geometry		
	depth (h)	139.7	mm
	thickness (t)	6.3	mm
	A	26.4	cm2
		2640	mm2
	Iyy	589	cm4
	Iyy	5890000	mm4
	Sy	27.71	cm3
		27710	mm3
	Polar Moment J	1178	cm4
		11780000	mm4
	Radius of Gyration Iy	47.2	mm
	Radius of Gyration Ip	66.8	mm
	Elastic Section Modulus		
	Wy	84.3	cm3
		84300	mm3
	Shear Area Ay	13.39	cm2
		1339	mm2
	Torsion Constant It	1177	cm4
		11770000	mm4
	Mpl,y	39.81	kNm
		39810000	Nmm
	Plastic Section Modulus		
	W ply	112	cm3
		112000	mm3
	G	20.7	kg/m
		0.203067	kN/m
	π	3.14159265	
	fy steel	355	N/mm2
	E	210000	N/mm2

Partial Safety Factors

Structural Steel	γ_{m0} =	1	
Concrete	γ_{m1} =	1.5	
Reinforcement	γ_{m2} =	1.15	
Shear Connectors	γ_{s} =	1.25	
Longitudinal Sh	γ_{vs} =	1.25	

Section Classification Check

EN 1993-1-1:2005
Table 5.2

For Tubular Section

d	139.70	mm
t	6.30	mm
ε	0.81	
d/t < = 50ε2		
c/t	22.17	
50ε2	**33.09859155**	

SECTION CLASS 1 | 0.67

Tension and Compression Check

From RFEM 6 Model

Nt	328	kN

EN 1993-1-1:2005
6.2.3

$$N_{pl,Rd} = \frac{A f_y}{\gamma_{M0}}$$

N pl,Rd	937200.00	N
	937.20	kN

Nt/N pl,Rd 0.34997866 — TENSION CHECK | 0.34997866

Nc	545	kN

Nc/ N pl,Red 0.58151942 — COMPRESSION CHECK | 0.58151942

Moment Capacity for Major Axis in Steel

From RFEM 6 Model

My Ed	25.18	kNm

$$M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl}\, f_y}{\gamma_{M0}} \quad \text{for class 1 or 2 cross sections}$$

McRd	39760000	Nmm
	39.76	kNm

	M Ed/ M pl,y,Rd 0.633299799 MOMENT CAPACITY	0.6333
	Moment Capacity Mz Axis in Steel From RFEM 6 Model Mz Ed 17.02 kNm $M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}}$ for class 1 or 2 cross sections McRd 39760000 Nmm 39.76 kNm M Ed/ M pl,y,Rd 0.42806841 MOMENT CAPACITY	0.4281
EN 1993-1-1:2005 6.3.1.2	**Flexural Buckling Check** From RFEM 6 Model N Ed 545 kN l eff 1.715 m l eff squared 1715000 mm2 $P_{cr} = \frac{\pi^2 EI}{(KL)^2}$ P cr 7118200.399 N 7118.200399 kN $\bar{\lambda} = \sqrt{\frac{Af_y}{N_{cr}}}$ for Class 1, 2 and 3 cross-sections - λ 0.362853265 $\Phi = 0,5\left[1 + \alpha(\bar{\lambda} - 0,2) + \bar{\lambda}^2\right]$ α 0.21 Φ 0.582930839	

EN 1993-1-1:2005 *6.3.1.1*	$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \overline{\lambda}^2}} \quad \text{but } \chi \leq 1{,}0$$ X 0.962314881 $$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}} \quad \text{for Class 1, 2 and 3 cross-sections}$$ N b,Rd 901881.5065 N 901.8815065 kN Ned/Nb,Rd 0.604292245 BUCKLING CHECK	0.604292245
	Moment Capacity for Combined Check From RFEM 6 Model My Ed (comb.) 6.06 kNm $$M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}} \quad \text{for class 1 or 2 cross sections}$$ McRd 39760000 Nmm 39.76 kNm M Ed/ M pl,y,Rd 0.152414487 MOMENT CAPACITY MAJOR AXIS CHECK	0.1524
	From RFEM 6 Model Mz Ed 0.31 kNm $$M_{c,Rd} = M_{pl,Rd} = \frac{W_{pl} f_y}{\gamma_{M0}} \quad \text{for class 1 or 2 cross sections}$$ M cRd 39760000 Nmm 39.76 kNm M Ed/ M pl,z,Rd 0.007796781 MOMENT CAPACITY MINOR AXIS CHECK	0.0078

EN 1993-1-1:2005 6.2

Combined Axial and Bending Effects

$$\frac{N_{Ed}}{N_{Rd}} + \frac{M_{y,Ed}}{M_{y,Rd}} + \frac{M_{z,Ed}}{M_{z,Rd}} \leq 1$$

Ned	545	kN
Nrd	901.8815065	kN
Myed	6.06	kNm
Myrd	39.76	kNm
Mzed	0.31	kNm
Mzrd	39.76	kNm

0.764503512

COMBINED AXIAL + MOMENT CHECK 0.7645

Shear Force Check

From RFEM 6 Model

V Ed	20.05	kN
	1.286	m

EN 1993-1-1: 2005 Clause 6.2.6

$$V_{pl,Rd} = \frac{A_v \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}}$$

V pl,Rd	274440.5637	N
	274.4405637	kN
V Ed/ Vpl,Rd	0.073057713	

SHEAR FORCE CHECK 0.073

Torsion Check

Calculation Torsional Stiffness

J	1178	cm4
	11780000	mm4

G= $\frac{E}{2(1+v)}$

v or steel	0.3	
G=	80769.2308	N/mm2

Torsional Stiffness= G.J

Torsional Stiffness= 9.5146E+11 Nmm2

Shear Stess

EN 1993-1-1: 2005

Clause 6.2.5

Eq: 6.2

$$\tau_{Ed} = \frac{V_{Ed}\, S}{I\, t}$$

Ved	12.04	kN
torsional stress	8.990982833	N/mm2

Verifying the design elastic shear resistance:

EN 1993-1-1: 2005

Clause 6.2.5

Eq: 6.19

$$\frac{\tau_{Ed}}{f_y / \left(\sqrt{3}\, \gamma_{M0}\right)} \leq 1{,}0$$

0.043867152

SHEAR RESISTANCE CHECK OK 0.043867152

Torsional Shear Stress

Torsional Moment from RFEM Model

Mt (T Ed)	6.22	kNm
length	1.286	m

torsional stress= Mt.r / J

where r = h= / 2 69.85 mm

applied torsional stress	8.99098283	N/mm2
torsional stress	36.88174873	N/mm2

applied torsional stress / resistant torsional stress <1

0.24377865

TORSIONAL STRESS CHECK OK 0.243778648

T pl,Rd	39810000	Nmm
T pl,Rd	39.81	kNm

	T Ed / T pl,Rd <1	
	T Ed / T pl,Rd 0.15624215	
	SHEAR AND TORSION CHECK OK	0.15624215
EN 1993-1-1: 2005 *Clause 6.2.5* *Eq: 6.19*	$$\frac{\tau_{Ed}}{f_y/\left(\sqrt{3}\,\gamma_{M0}\right)} \leq 1{,}0$$	
	0.179946655 SHEAR RESISTANCE CHECK OK	0.179946655
	Combined Shear and Torsional Moment	
EN 1993-1-1: 2005 *Clause 6.2.7* *Eq: 6.28*	$$V_{pl,T,Rd} = \left[1 - \frac{\tau_{t,Ed}}{\left(f_y/\sqrt{3}\right)/\gamma_{M0}}\right] V_{pl,Rd}$$	
	V pl,Rd 274.4405637 kN	
	V pl,T,Rd 225.0559022 kN	
	V Ed / Vpl,Rd <1	
	0.053497819	
	REDUCED PLASTIC SHEAR RESISTANCE CHECK OK	0.053497819
	Calculating angle of twist	
SCI:P 358 Torsion *Elastic Theory of Torsion*	$$\phi' = T/GI_T$$	
	θ= 0.008414125 radians	
	0.482093833 degrees	
	for glass θ < 2	
	0.241046917	
	TWISTING ANGLE OK	0.241046917
	Torsional Moment Resistance	
	M T,Rd = fy. J / r . γ	
	M T,Rd = 59869720.83 Nmm	
	59.86972083 kNm	

Mt < 1
M T,Rd
Mt = 0.10389225
M T,Rd

TORSIONAL RESISTANCE CHECK OK 0.10389225

Global Deflection Check

Deflection from RFEM Model

Δ global	10.5	mm
Δ global <=	L 500	
L=	32	m
Δ global allowable	64	mm

Δ global / Δ global allowable <1

0.1640625

GLOBAL DEFLECTION CHECK OK 0.1640625

Relative Local Deflection Check

Deflection from RFEM Model

Δy local	0.7	mm
L	3.297	m
	3297	mm
Δ local <=	L 500	
Δ local allowable	6.594	mm

Δ local / Δ local allowable <1

0.106157113

LOCAL DEFLECTION CHECK OK 0.106157113

Local Deflection Check

Deflection from RFEM Model

Δz local	2	mm
L	1.948	m
	1948	mm
Δ local <=	L 500	

	Δ local allowable 3.896 mm $\frac{\Delta \text{ local}}{\Delta \text{ local allowable}}$ <1 0.513347023 LOCAL DEFLECTION CHECK OK	0.513347023

CVE 5010- Thesis Project	
L-Università ta' Malta	**Subject:** Pin Connection
CALCULATION BOOKLET	**Name:** Matthew Rapa — **Date:** 19/03/2025

Axial Force in Bracing

Ned	57.8209902	kN

Pin Details

d	30	mm
do	40	mm
π	3.141592654	
A	706.8583471	mm2
fy	460	N/mm2
fup	460	N/mm2

<u>Plate Properties</u>

0.3do	12	mm
0.75do	30	mm
1.3do	52	mm
1.6do	64	mm
Width of plate Is 2.5x dc	100	mm
	220	mm
h	165	mm
tp	20	mm
fya	410	N/mm2
fu	410	N/mm2
No. pins	1	
No. plates	3	
N ed/plate	19.2736634	kN
1.6*d = e1 min	64	mm
e1	235	mm
0.7*d= e2 min	28	mm
e2	110	mm

<u>Plate thickness check</u>

$$t \geq 0.7\left(\frac{V_{Ed}\gamma_{mo}}{f_y}\right)^{0.5}$$

t min	4.799414361	mm
	0.239970718	Check ok

Bolt thickness

$d_0 \leq 2.5t$

2.5t	50	mm
	0.8	Check ok

Shear Resistance of pin

$$F_{v,Rd} = \frac{0.6 f_{up} A}{\gamma_{m2}}$$

F v,Rd	156.074323	kN

However, 5 plates are used

F v,Rd / plate	31.21486461	kN

Bearing Resistance of Plate with in

$$F_{b,Rd,ser} = 0.6\text{t. d. } f_y . \gamma_{m6,ser}$$

F b,Rd,ser	442.8	kN/plate

Bending Resitance of Pin

$$M_{Ed} = \frac{F_{Ed}\,(b + 4c + 2a)}{8}$$

c	15	mm
L pin	120	mm
M ed	0.289104951	kNm

$$M_{Rd,ser} = 0{,}8\ W_{el}\ f_{yp}/\gamma_{M6,ser}$$

Wel	2650.718801	mm3
M Rd,Ser	0.975464519	kNm

Combined Shear and Bending of pin

$$\left[\frac{M_{Ed}}{M_{Rd}}\right]^2 + \left[\frac{F_{v,Ed}}{F_{v,Rd}}\right]^2 \leq 1$$

0.469085438

Shear Resistance of Gusset Plate

$$A_v = \text{t x h}$$

Av	3300	mm2

$$V_{pl,Rd} = \frac{A_v\ f_y}{\sqrt{3}\,\gamma_{mo}}$$

V pl,Rd	781.1549142	kN
V pl,Rd	2343.464743	kN

Net area

$$A_{v,net} = \text{t (h} - \text{do)}$$

A v,net	2500	mm2

$$V_{pl,Rd} = \frac{A_v\ f_y}{\sqrt{3}\,\gamma_{mo}}$$

V pl,Rd	591.7840259	kN/plate
V pl,Rd	1775.352078	kN

Design shear resistance of the weld:

$$f_{vw,d} = \frac{f_u/\sqrt{3}}{\beta_w \gamma_{M2}}$$

fu of weld	510	N/mm2
β=	0.9	
f vw,d	261.732122	N/mm2
s< 0.8tp		
s	16	mm
therefore take s to be	15	mm
a=0.7s		
a=0.7s	10.5	mm

$$F_{w,Rd} = f_{vw,d}\,a$$

F w,Rd	2748.187281	N/mm

Shear Strength of Weld

F w,Rd * (nbp -4s)

Shear strength	1648.912369	kN

Shear Stress of Connection

Actual Weld length	2250	
V ed	25.69821787	N/mm
V ed/FwRd	0.00935097	
	Check ok	

L-Università ta' Malta	CVE 5010- Thesis Project	
	Subject: Steel column base plate	
CALCULATION SHEET	Name: Matthew Rapa	Date: 19/3/2025

Unless stated otherwise, all references are to EN 1993-1-8:2005

Axial load in column:

Axial force, N_{Ed} = 57.82099 kN

V_{Ed} = 56.073991 kN

Column section:

CHS 139.7x6.3

Yield Strength =	355	N/mm^2
Area of Section =	26.4	cm^2
Second moment of area, I =	589	cm^4
d =	139.7	mm
t =	6.3	mm

Base Plate properties:

300 x 285 x 17.5

Depth of plate (h_p) =	300	mm
Width of plate (b_p) =	285	mm
Thickness of plate (t_p) =	17.5	mm
Yield strength of plate (f_{yp}) =	355	N/mm^2
Ultimate srength (f_u) =	470	N/mm^2

EN 1993-1-1
EN 10025-2

Required area of base plate

Basic requirement = $A_p \geq A_{req}$

Area of base plate (A_p) = $h_p \times b_p$

A_p = 85500 mm^2

Design compressive strength of the concrete:

SN017
Section 15

$$f_{cd} = \alpha_{cc} \frac{f_{ck}}{\gamma_c}$$

f_{ck} = 30 N/mm^2 *(axial)*

α_{cc} = 0.85

γ_c = 1.5

f_{cd} = 17 N/mm^2

National Annex
EN 1992-1-1

$$f_{jd} = \beta_j \, \alpha \, f_{cd}$$

β_j = 0.67

α = 1.5

f_{jd} = 17 N/mm^2

$$A_{req} = \frac{N_{Ed}}{f_{jd}}$$

A_{req} = 3401.2347 mm^2

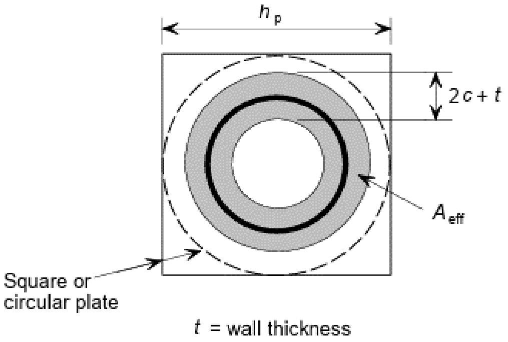
A 85500 mm^2

0.039781

Effective area:

Basic requirement: $A_{req} \leq A_{eff}$

SCI - P358
Section 5.5



Assuming no overlap:

For CHS column $A_{eff} = \pi (d - t)(t + 2c)$

Expansion & simplification =

A_{eff} - dπt + t^2π

SCI - P358
Section 5.5

$A_{eff} = A_{req}$ =	3401.2347	mm^2
dπt =	2764.9471	mm^2
πt^2 =	124.68981	mm^2
2πd =	877.76099	mm
2πt =	39.584067	mm
c =	0.9078959	mm
c =	1	mm

When there is overlap: $c \geq \frac{d - 2t}{2}$

1 ≤ 63.55 mm

No overlap present

To check that the effective area fits on the base plate:

d + 2c = 141.7 < mm

C CHECK OK

0.472333

SCI - P358 *Section 5.5*	**Base plate thickness:** $t_{p,min} = c\sqrt{\dfrac{3 f_{jd} \gamma_{M0}}{f_{yp}}}$ $t_{p,min}$ = 0.38 mm < 17.5 mm Thus, 20mm plate thickness is sufficient. **Weld design:** $F_{w,Rd} = f_{vw.d}\, a$ $\qquad f_{vw.d} = \dfrac{f_u / \sqrt{3}}{\beta_w \gamma_{M2}}$ s = 6 mm | β_w = 0.9 a = 4.2 mm | $f_{vw,d}$ = 241.20 $F_{w,Rd}$ = 1013.06 N/mm	
SCI - P358 *Section 5.5*	$V_{Ed} \le F_{w,Rd}\, \ell_{w,eff}$ $l_{w,eff} = 2\pi d/4$ = 219.44025 mm $F_{w,Rd} \times l_{w,eff}$ = 222.31 kN $V_{Ed} / F_{w,Rd} l_{w,eff}$ = 0.25	0.252238

CVE 5010- Thesis Project	
L-Università ta' Malta	**Subject:** BEAM OVER STAIRCASE
CALCULATION SHEET	**Name:** Matthew Rapa — **Date:** 19/03/2025

EN 1991-2 Section 6.3.7			
	Live Load		
	qfk =	4	kN/m2
	qfk with SF=	6	kN/m2
	Beam Properties		
	Beam span	3.5	m
	Bay Width (a)	1.5	m
	Length (*l*)	3.5	m
	load (kN/m)	9	kN/m
	RHS 260x180x6.3		
	Depth (h)	260	mm
		0.26	m
	Width (b)	180	mm
		0.18	m
	t	10	mm
	root radius	15	mm
	A	8293	mm2
	Izz	43510000	mm4
	Iyy	77410000	mm4
	W ely	595000	mm3
	W ply	723600	mm3
	Avz	4900	mm2
	Avy	3392	mm2
	fy	355	N/mm2
	Dead Load of	65.1	kg/m
		0.638631	kN/m
	Factored Dead Load	0.9579465	kN/m

	Unfactored Dead LoadDeck 1 kN/m2	
	Factored Dead Load 1.35 kN/m2 2.025 kN/m	
	Total Factored Load 11.982947 kN/m	
	Applied Moment M ed <u>Wl2</u> 8 Med 18.348887 kN	
	Applied Shear Ved <u>WL</u> 2 V ed 20.970156 kN	
EN 1993-1-1 *Table 5.2*	**Outstand Flange** c=b-2t	
	fy 355 N/mm2 ε 0.8136165	
	c 160 c/t 16 33 ε 26.849345	
	c/tf < 9 ε 0.5959177	
	FLANGE IN CLASS 1	0.595917704
	Internal compression part	
EN 1993-1-1 *Table 5.2*	c=h-2t	
	c 240 c/t 24 33 ε 26.849345 0.8938766	
	WEB IS IN CLASS 1	0.893876556

EN 1193-1-1 *6.2.5*	**Moment Resistance** $$M_{c,Rd} = M_{pl,Rd} = W_{pl,y} f_y / \gamma_{M0}$$ Mpl,Rd 256.878 kNm MyEd/Mcrd 0.0714304 <1 MOMENT RESISTANCE CHECK OK	0.071430355
EN 1993-1-5:2005 *Clause 5.3*	Determine the Web Slenderness Ratio $$\lambda_w = \frac{h_w}{t_w}\sqrt{\frac{f_y}{E}}$$ hw 240.00 mm λ 0.98677 Therefore since λ is <1, web is stocky For stocky RHS	
EN 1993-1-1 *6.2.6*	**Shear plastic Resistance** $$V_{pl,Rd} = \frac{A_v \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}}$$ 696046.2428 N 696.0462428 kN Vy,Ed/ V pl,y,Rd 0.0301275 <1 SHEAR PLASTIC RESISTANCE Y-AXIS CHECK OK	0.030127533
EN 1993-1-1 *6.2.8*	**Interaction between bending moment and shear force** $$V_{z,Ed} < V_{pl,Rd} / 2$$ Vpl,Rd / 2 348.02312 Vz,Ed 20.970156 0.0602551 INTERACTION CHECK OK	0.060255067

EN 1993-1-1

6.2.6

Shear plastic Resistance

$$V_{\mathrm{pl,Rd}} = \frac{A_v \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}}$$

1005491.329 N

1005.491329 kN

Vz,Ed/
V pl,z,Rd 0.000889 <1

SHEAR PLASTIC RESISTANCE Z-AXIS CHECK OK 0.000888995

Deflection Check

$$\delta = \frac{5wL^4}{384EI}$$

w	11.982947	N/mm
L	3.5	m
	3500	mm
E	210000	N/mm2
I	77410000	mm4
deflction	1.4403174	mm

Allowable Deflection

L = 14 mm

250

0.1028798

DEFLECTION CHECK OK 0.102879816

L-Università ta' Malta	**CVE 5010- Thesis Project**
	Subject: CANTILEVERED BEAM
CALCULATION SHEET	**Name:** Matthew Rapa / **Date:** 19/03/2025

EN 1991-2
Section 6.3.7

Beam Properties

Beam span	2.2	m
a	1.75	m
UDL from beam	11.982947	kN/m
Length	3.5	
Point Load	41.940313	kN

RHS 200x100x10

Depth (h)	200	mm
	0.2	m
Width (b)	100	mm
	0.1	m
t	10	mm
radius	15	mm
A	5493	mm2
Iyy	26640000	mm4
Izz	8688000	mm4
W ely	266400	mm3
W ply	340900	mm3
Avy	1831	mm2
Avz	3662	mm2
E	210000	N/mm2
fy	355	N/mm2
Dead Load of Secondary Beam	43.1	kg/m
	0.422811	kN/m
Factored Dead Load	0.6342165	kN/m

Applied Moment

M ed $\frac{Wl^2}{8}$ + wl

Med 73.7792483 kNm

Applied Shear
Ved W + Wl

V ed 43.33558905 kN

Outstand Flange

EN 1993-1-1
Table 5.2

c=b-2t

fy 355 N/mm2
ε 0.813616513

c 80
c/t 8
33 ε 26.84934494

c/tf < 33 ε
0.297958852

FLANGE IN CLASS 1 | 0.297958852

Internal compression part

EN 1993-1-1
Table 5.2

c=h-2t

c 180
c/t 18
33 ε 26.84934494
0.670407417

WEB IS IN CLASS 1 | 0.670407417

Moment Resistance

EN 1193-1-1
6.2.5

$$M_{c,Rd} = M_{pl,Rd} = W_{pl,y} f_y / \gamma_{M0}$$

Mpl,Rd 121.0195 kNm
MyEd/Mcrd 0.609647605 <1
MOMENT RESISTANCE CHECK OK | 0.609647605

EN 1993-1-5:2005
Clause 5.3

Determine the Web Slenderness Ratio

$$\lambda_w = \frac{h_w}{t_w}\sqrt{\frac{f_y}{E}}$$

	hw 180.00 λ 0.74007722 Therefore since λ is <1, web is stocky For stocky RHS	
EN 1993-1-1: 2005 *Clause 6.2.6*	$$V_{pl,Rd} = \frac{A_v \cdot f_y}{\sqrt{3} \cdot \gamma_{M0}}$$	
	V pl,Rd 375280.562 N 375.280562 kN V Ed/ Vpl,Rd 0.00162451	
	SHEAR PLASTIC RESISTANCE Y-AXIS CHECK	0.00162
EN 1993-1-1 *6.2.6*	$$V_{pl,z,Rd} = \frac{A_{v,z}\,(f_y / \sqrt{3})}{\gamma_{M0}}$$	
	751450.8671 N 751.4508671 kN	
EN 1993-1-1 *6.2.8*	Vz,Ed/V pl,z,Rd 0.057669225 <1	
	SHEAR PLASTIC RESISTANCE Z-AXIS CHECK OK	0.057669225
	Deflection Check $$\delta_{max} = \frac{wL^4}{8EI}$$	
	w 0.6342165 N/mm L 2200 mm E 210000 N/mm2 I 26640000 mm4 deflection 0.331959237 mm	

$$\delta_{max} = \frac{Pa^2(3L-a)}{6EI}$$

P	41940.31275	N
L	2.2	m
	2200	mm
a	1750	mm
E	210000	N/mm2
I	26640000	mm4
deflction	5.165790211	mm

Allowable Deflection

$\frac{L}{250}$ = 8.8 mm

0.6247443

DEFLECTION CHECK OK 0.624744255

L-Università ta' Malta	**CVE 5010- Thesis Project**
	Subject: COLUMN SUPPORT
CALCULATION SHEET	**Name:** Matthew Rapa — 19/03/2025

Column largest length	0.7316	m
Column largest effective length	0.7316	m
Timber Span	1.5	m
	0.75	m
Deck Dead Load		
POINT LOAD	41.94031275	kN
Trial RHS 180x100x12.5		
Depth h	150	mm
Width b	100	mm
thickness t	12.5	mm
outer radius	18.8	
Area	5457	mm2
Second Moment of Area	14880000	mm4
Wpl	256200	mm3
Wel	198400	mm3
V pl,Rd	671.12	kN
M pl,Rd	67.47	kNm
G	42.8	kg/m
fy	355	N/mm2
π	3.141592654	
E	210000	N/mm2
Columns		
Self Weight	42.8	kg/m
	0.419868	kN/m
length	0.7316	m
Factored Self-Weight	0.414686829	kN
Total Load	42.35499958	kN

	Web Class c=h-2t fy 355 N/mm2 ε 0.813616513 c 125 mm c/tw 10 33 ε 26.84934494 c/tw < 33 ε 0.372448565 WEB IN CLASS 1	 0.372448565
EN 1993-1-1 *Table 5.2*	**Flange Class** c=b-2t fy 355 N/mm2 ε 0.813616513 c 75 mm c/t 6 33 ε 26.84934494 c/tf < 33 ε 0.223469139 FLANGE IN CLASS 1	 0.223469139
EN 1993-1-1,6.7	**Axial Load Check** $N_{pl,Rd} = \frac{A \cdot f_y}{\gamma_{M0}}$ N pl,Rd 1937235 N 1937.235 kN N ed 42.35499958 kN N ed/Npl,Rd 0.021863635 <1 AXIAL LOAD CHECK OK	 0.021863635

	Buckling Check	
	Compression Check	
EN 1993-1-1,6.49	$$N_{cr} = \frac{\pi^2 EA}{\lambda^2}$$	
	A - Second Moment of Area in this case	
	λ 731.6 mm	
	λ2 535238.56 mm2	
	Elastic Critical Buckling Constant 57620175.63 N	
EN 1993-1-1,6.49	$$\bar{\lambda} = \sqrt{\frac{Af_y}{N_{cr}}}$$	
	Non Dimensionless Slenderness 0.183359689	
EN1993-1-1,6.49	$$\Phi = 0.5\left[1 + \alpha\left(\bar{\lambda} - 0.2\right) + \bar{\lambda}^2\right]$$	
	o/ 0.515063155	
EN 1993-1-1,6.49	$$\chi = \frac{1}{\Phi + \sqrt{\Phi^2 - \bar{\lambda}^2}} \leq 1$$	
	Reduction Factor 1.003629622	
EN 1993-1-1,6.47	$$N_{b,Rd} = \frac{\chi A f_y}{\gamma_{M1}}$$ for class 1, 2, 3 cross-sections	
	Design Buckling Resistance Nbplrc 1944.266432 kN	
	N ed 42.35499958	
	Ned/Nbrd 0.021784566 <1	
	BUCKLING CHECK OK	0.021784566

	Elastic Bending Resistance Med 31.45523456 kNm fb M ed / S fb 158.544529 N/mm2 f all = 0.6*fy 213 N/mm2 Elastic Bending Resistance 0.744340512 ELASTIC BENDING RESISTANCE CHECK OK	 0.744340512

L-Università ta' Malta

CALCULATION SHEET

CVE 5010- Thesis Project

Subject: Foundation Stress

Made by: Matthew Rapa

Date: 19/3/2025

Unless stated otherwise, all references are to EN 1992-1-1 :2004

length	3.368	
	3368	
depth (h)	400	mm
	0.4	m
width (b)	1000	mm
	1	m
As	61.29	m2
	61290000	
No. of nodes	30	
Distance to Neutral Axis	16.81	m
Total Lateral Force	56.0739905	kN
Bending Moment	775.503289	kNm
I outer shape	365403360	m4
I inner shape	322299754	m4
I	43103606	m4
Axial Stress	0.00030244	kN/m2
Axial Force	176822.6	kg
	1734629.71	N
	1734.62971	kN
	57.8209902	kN/node
Axial Stress in Compression	28.3020021	kN/m2
Axial Stress inTension	-28.3017	kN/m2
Axial Stress in Compression	-28.3023	kN/m2

Therefore foundation is in Compression

Project data

Project name	
Project number	
Author	
Description	
Date	3/5/2025
Code	EN

Material

Steel	S 355

Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

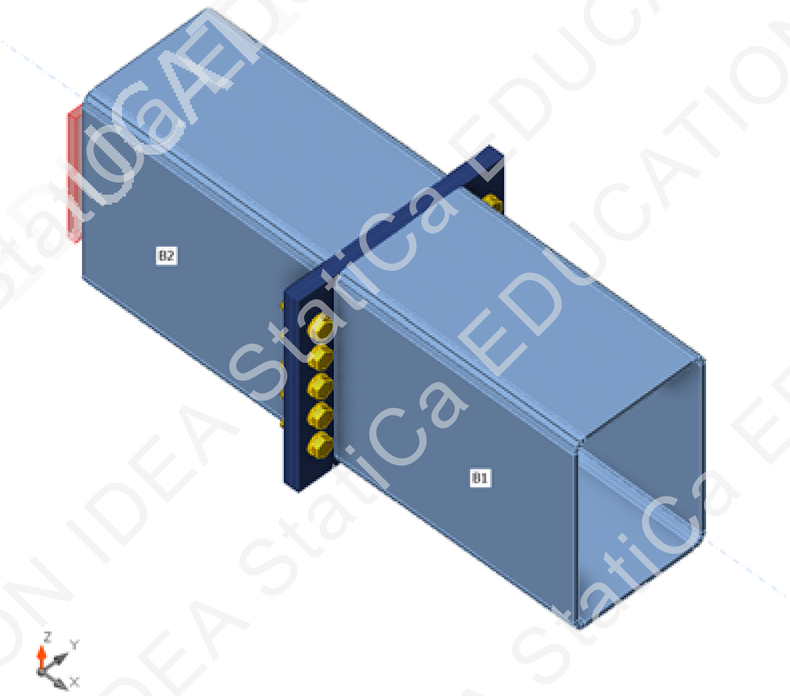
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
B1	1 - RHSCF260/180/6.3	0.0	0.0	0.0	0	0	0
B2	1 - RHSCF260/180/6.3	180.0	0.0	0.0	0	0	0

Supports and forces

Name	Support	Forces in	X [mm]
B1 / end		Node	0
B2 / end	N-Vy-Vz-Mx-My-Mz	Node	0



Cross-sections

Name	Material
1 - RHSCF260/180/6.3	S 355

Bolts

Name	Diameter [mm]	f_y [MPa]	f_u [MPa]	Gross area [mm^2]
M14 8.8	14	640.0	800.0	154

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B1 / End	0.0	22.0	-10.0	0.0	20.0	0.0
	B2 / End	0.0	22.0	10.0	0.0	20.0	0.0

Unbalanced forces

Name	X [kN]	Y [kN]	Z [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	0.0	0.0	0.0	0.0	0.0	0.0

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Loc. deformation	0.1 < 3%	OK
Bolts	78.8 < 100%	OK
Welds	0.0 < 100%	OK
Buckling	Not calculated	
GMNA	Calculated	

Plates

Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
B1	6.3	LE1	256.0	0.0	0.0	OK
B2	6.3	LE1	261.8	0.0	0.0	OK
PP1a	10.0	LE1	351.5	0.0	70.9	OK
PP1b	10.0	LE1	352.0	0.0	70.9	OK

Design data

Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

Symbol explanation

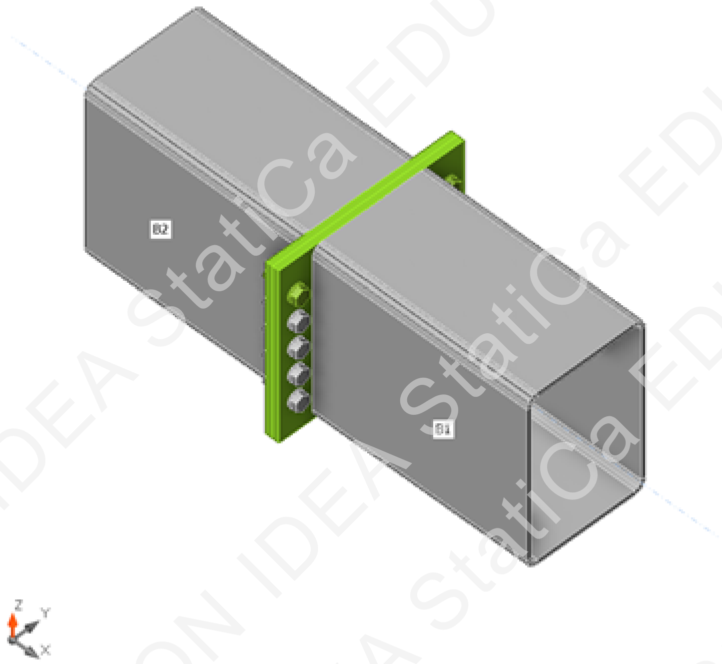
t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain

Loc. deformation

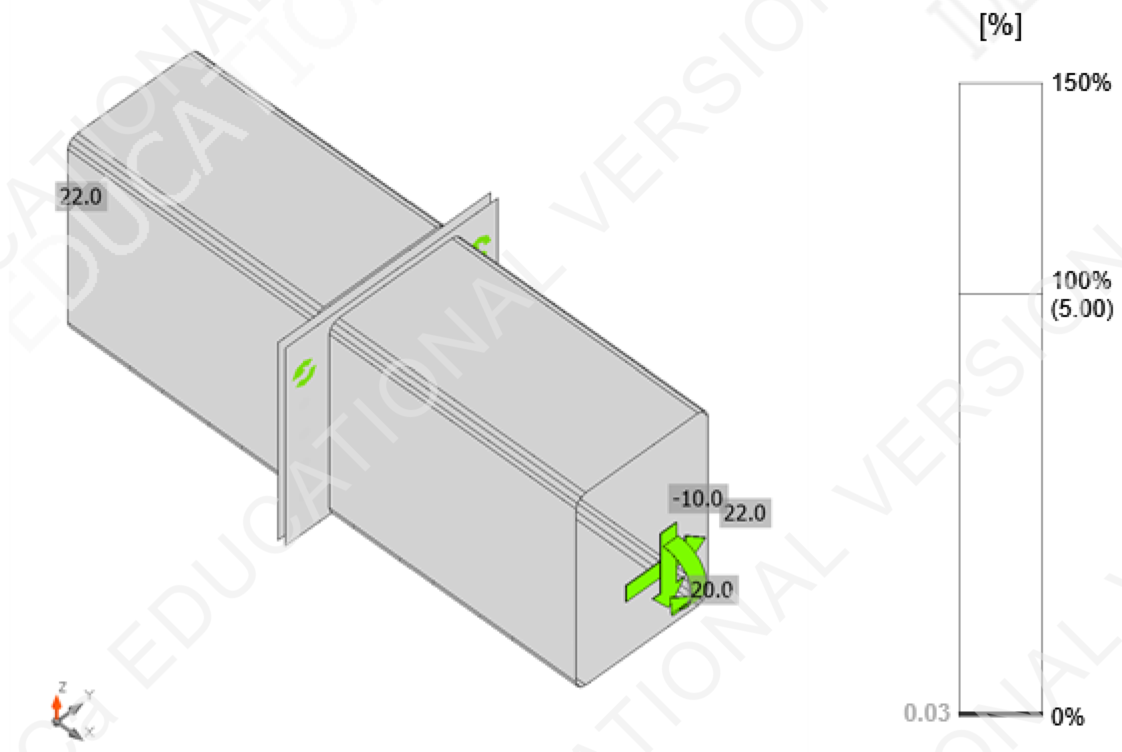
Name	d_0 [mm]	Loads	δ [mm]	δ_{lim} [mm]	δ/d_0 [%]	Check status
B1	180	LE1	0	5	0.1	OK
B2	180	LE1	0	5	0.1	OK

Symbol explanation

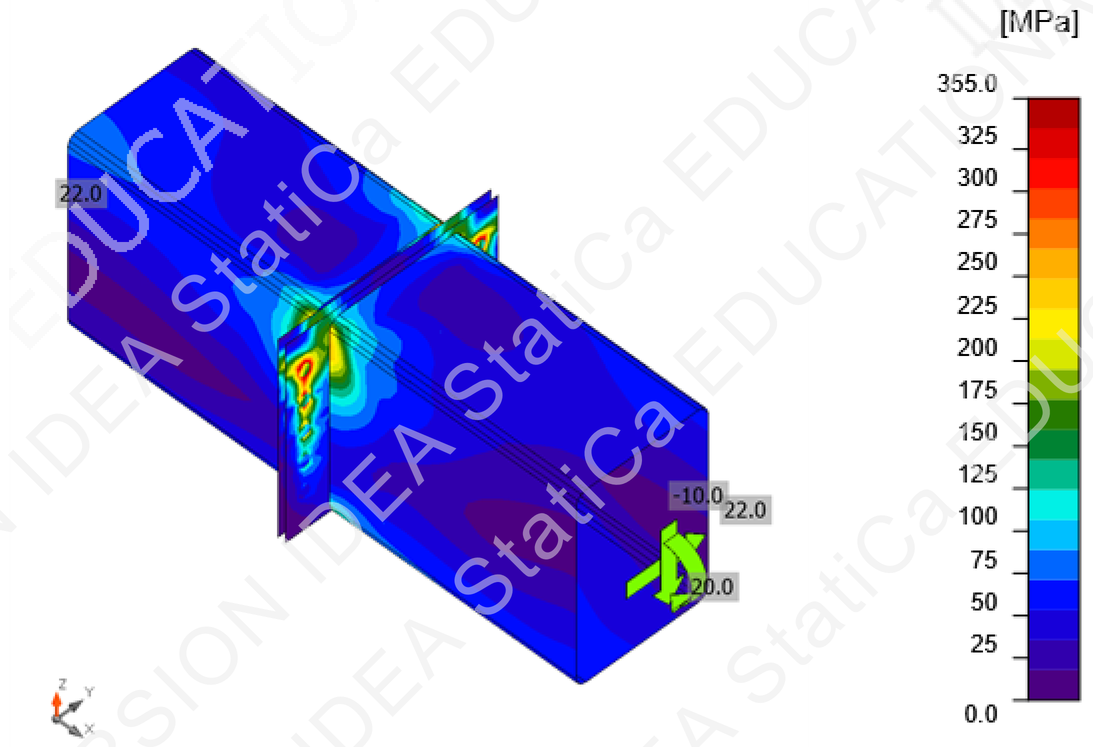
d_0	Cross-section size
δ	Local cross-section deformation
δ_{lim}	Allowed deformation



Overall check, LE1

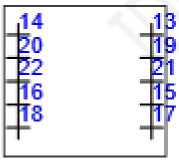


Strain check, LE1



Equivalent stress, LE1

Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B13	M14 8.8 - 1	LE1	52.3	2.6	71.5	78.6	5.9	62.0	OK	OK
	B14	M14 8.8 - 1	LE1	52.4	2.5	51.5	78.8	5.6	61.9	OK	OK
	B15	M14 8.8 - 1	LE1	10.4	2.3	51.4	15.6	5.2	16.3	OK	OK
	B16	M14 8.8 - 1	LE1	10.4	2.4	71.5	15.6	5.4	16.6	OK	OK
	B17	M14 8.8 - 1	LE1	2.9	2.5	51.4	4.4	5.5	8.7	OK	OK
	B18	M14 8.8 - 1	LE1	3.1	2.6	71.5	4.6	5.9	9.3	OK	OK
	B19	M14 8.8 - 1	LE1	28.9	2.4	71.5	43.4	5.4	36.4	OK	OK
	B20	M14 8.8 - 1	LE1	29.0	2.3	51.5	43.6	5.2	36.3	OK	OK
	B21	M14 8.8 - 1	LE1	18.9	2.3	71.5	28.4	5.2	25.5	OK	OK
	B22	M14 8.8 - 1	LE1	18.9	2.3	71.5	28.4	5.2	25.5	OK	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M14 8.8 - 1	66.5	163.9	44.3

Symbol explanation

$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4

Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
PP1a	B1-w 1	-	832	-	-	-	-	-	-	-	-	OK	OK
PP1b	B2-w 1	-	832	-	-	-	-	-	-	-	-	OK	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.0	-	-	-

Symbol explanation

T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
ε_{Pl}	Strain
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\perp}$	Shear stress perpendicular to weld axis
$\tau_{\parallel}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
Safety factor γ_{M0}	1.00	-	EN 1993-1-1 – 6.1
Safety factor γ_{M1}	1.00	-	EN 1993-1-1 – 6.1
Safety factor γ_{M2}	1.25	-	EN 1993-1-1 – 6.1
Safety factor γ_{M3}	1.25	-	EN 1993-1-8 – Table 2.1
Safety factor γ_C	1.50	-	EN 1992-1-1 – 2.4.2.4
Safety factor γ_{Inst}	1.20	-	EN 1992-4 – Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8 – 6.2.5(7)
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 – Table 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	Yes		
Distance between bolts [d0]	2.20	-	EN 1993-1-8 – Table 3.3
Distance between bolts and edge [d0]	1.20	-	EN 1993-1-8 – Table 3.3
Concrete breakout resistance check	Both		
Use calculated αb in bearing check.	Yes		EN 1993-1-8 – Table 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	Yes		
Local deformation limit	0.03	-	CIDECT DG 1, 3 – 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8 – 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	5/9/2016
Code	EN

Material

Steel	S 235, S 355
Concrete	C25/30

Project:
Project no:
Author:

Project item Tubular

Design

Name	Tubular
Description	
Analysis	Stress, strain/ simplified loading

Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
B1	11 - CHS HF 139,7x6,3	0.0	0.0	0.0	0	0	0
B2	11 - CHS HF 139,7x6,3	180.0	0.0	0.0	0	0	0

Supports and forces

Name	Support	Forces in	X [mm]
B1 / end	N-Vy-Vz-Mx-My-Mz	Bolts	0
B2 / end		Bolts	0

Cross-sections

Name	Material
11 - CHS HF 139,7x6,3	S 355

Bolts

Name	Diameter [mm]	f_y [MPa]	f_u [MPa]	Gross area [mm^2]
M20 10.9	20	900.0	1000.0	314

Load effects (Equilibrium not required)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B2 / End	41.0	20.1	2.4	0.0	25.6	0.0

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	2.4 < 5.0%	OK
Bolts	92.9 < 100%	OK
Welds	0.0 < 100%	OK
Buckling	Not calculated	
GMNA	Calculated	

Plates

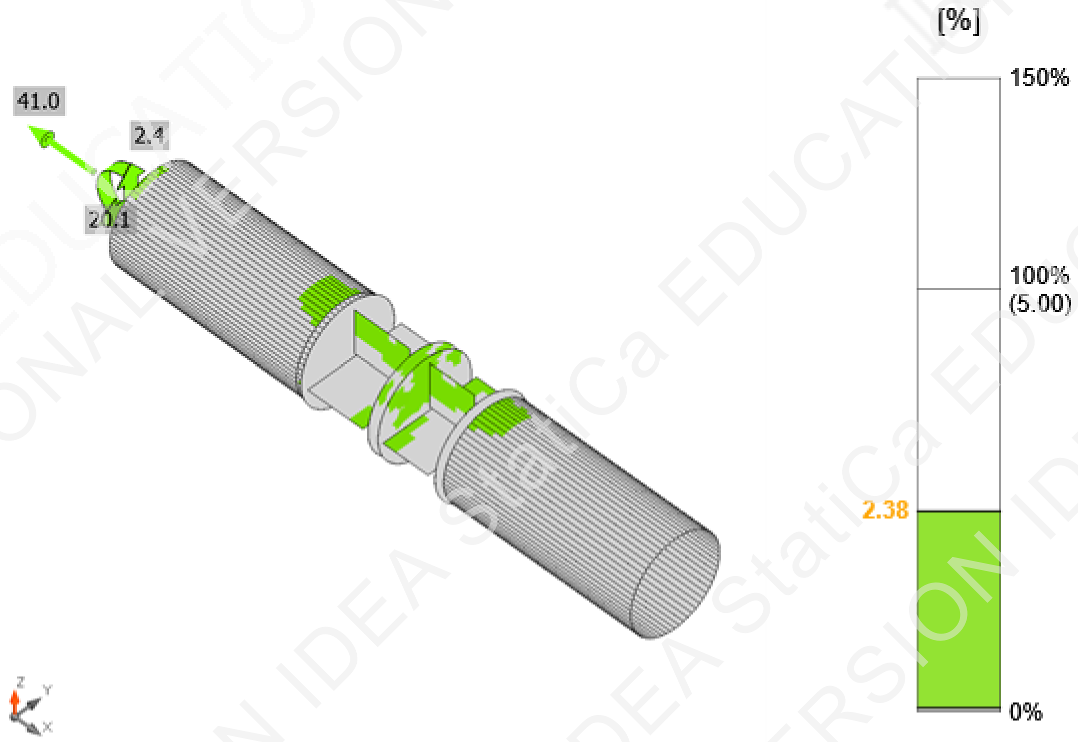
Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
B1	6.3	LE1	355.7	0.3	0.0	OK
B2	6.3	LE1	355.8	0.4	0.0	OK
SP1	20.0	LE1	312.8	0.0	0.0	OK
SP2	20.0	LE1	334.3	0.0	0.0	OK
SP3	15.0	LE1	356.2	0.6	343.8	OK
SP4	15.0	LE1	356.3	0.6	343.8	OK
SP5	10.0	LE1	355.5	0.2	0.0	OK
SP6	10.0	LE1	355.5	0.2	0.0	OK
SP7	16.0	LE1	356.5	0.7	0.0	OK
SP8	16.0	LE1	360.0	2.4	0.0	OK
SP9	16.0	LE1	356.6	0.7	0.0	OK
SP10	16.0	LE1	360.0	2.4	0.0	OK

Design data

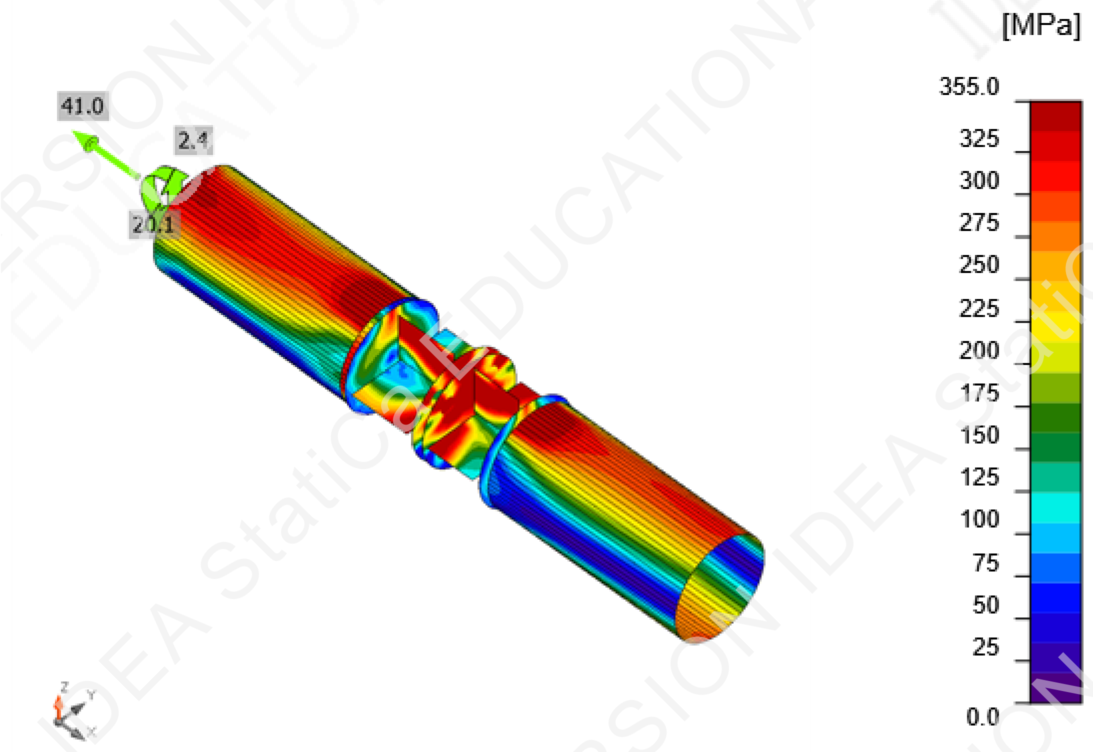
Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

Symbol explanation

t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain

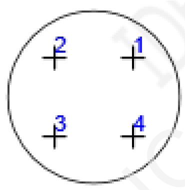


Strain check, LE1



Equivalent stress, LE1

Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Status
	B1	M20 10.9 - 1	LE1	23.8	6.7	65.7	13.5	10.2	16.5	OK
	B2	M20 10.9 - 1	LE1	163.9	3.4	64.6	92.9	5.2	69.8	OK
	B3	M20 10.9 - 1	LE1	163.8	3.3	64.6	92.9	5.1	69.7	OK
	B4	M20 10.9 - 1	LE1	22.6	7.2	71.7	12.8	10.1	16.5	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M20 10.9 - 1	176.4	352.1	98.0

Symbol explanation

$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4

Project:
Project no:
Author:

Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_\perp$ [MPa]	$\tau_\perp$ [MPa]	$\tau_{\|\|}$ [MPa]	Ut [%]	Ut_c [%]	Status
SP1	SP5	-	140	-	-	-	-	-	-	-	-	OK
SP3	SP5	-	140	-	-	-	-	-	-	-	-	OK
SP2	SP6	-	140	-	-	-	-	-	-	-	-	OK
SP4	SP6	-	140	-	-	-	-	-	-	-	-	OK
SP1	SP7	-	65	-	-	-	-	-	-	-	-	OK
SP3	SP7	-	65	-	-	-	-	-	-	-	-	OK
SP5	SP7	-	68	-	-	-	-	-	-	-	-	OK
SP1	SP8	-	65	-	-	-	-	-	-	-	-	OK
SP3	SP8	-	65	-	-	-	-	-	-	-	-	OK
SP5	SP8	-	68	-	-	-	-	-	-	-	-	OK
SP2	SP9	-	65	-	-	-	-	-	-	-	-	OK
SP4	SP9	-	65	-	-	-	-	-	-	-	-	OK
SP6	SP9	-	83	-	-	-	-	-	-	-	-	OK
SP2	SP10	-	65	-	-	-	-	-	-	-	-	OK
SP4	SP10	-	65	-	-	-	-	-	-	-	-	OK
SP6	SP10	-	83	-	-	-	-	-	-	-	-	OK
SP1	B1-arc 1	-	419	-	-	-	-	-	-	-	-	OK
SP2	B2-arc 1	-	419	-	-	-	-	-	-	-	-	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.0	-	-	-

Symbol explanation

T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
ε_{Pl}	Strain
$\sigma_\perp$	Perpendicular stress
$\tau_\perp$	Shear stress perpendicular to weld axis
$\tau_{\|\|}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
Safety factor γ_{M0}	1.00	-	EN 1993-1-1 – 6.1
Safety factor γ_{M1}	1.00	-	EN 1993-1-1 – 6.1
Safety factor γ_{M2}	1.25	-	EN 1993-1-1 – 6.1
Safety factor γ_{M3}	1.25	-	EN 1993-1-8 – Table 2.1
Safety factor γ_{C}	1.50	-	EN 1992-1-1 – 2.4.2.4
Safety factor γ_{Inst}	1.20	-	EN 1992-4 – Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8 – 6.2.5(7)
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 – Table 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	No		
Distance between bolts [d0]	2.20	-	EN 1993-1-8 – Table 3.3
Distance between bolts and edge [d0]	1.20	-	EN 1993-1-8 – Table 3.3
Concrete breakout resistance check	Both		
Use calculated αb in bearing check.	Yes		EN 1993-1-8 – Table 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	No		
Local deformation limit	0.03	-	CIDECT DG 1, 3 – 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8 – 5.2.2.5

Project data

Project name	
Project number	
Author	
Description	
Date	3/8/2025
Code	EN

Material

Steel	S 355

Project:
Project no:
Author:

Project item CON1

Design

Name	CON1
Description	
Analysis	Stress, strain/ loads in equilibrium

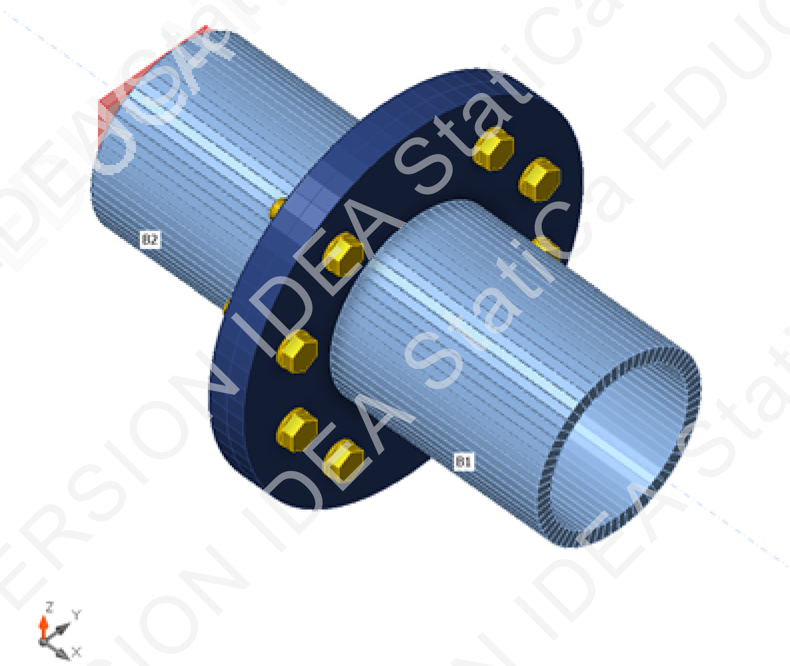
Members

Geometry

Name	Cross-section	β – Direction [°]	γ - Pitch [°]	α - Rotation [°]	Offset ex [mm]	Offset ey [mm]	Offset ez [mm]
B1	1 - CHS193.7/16.0	0.0	0.0	0.0	0	0	0
B2	2 - CHS193.7/16.0	180.0	0.0	0.0	0	0	0

Supports and forces

Name	Support	Forces in	X [mm]
B1 / end		Bolts	0
B2 / end	N-Vy-Vz-Mx-My-Mz	Bolts	0



Cross-sections

Name	Material
1 - CHS193.7/16.0	S 355
2 - CHS193.7/16.0	S 355

Bolts

Name	Diameter [mm]	f_y [MPa]	f_u [MPa]	Gross area [mm^2]
M20 10.9	20	900.0	1000.0	314

Load effects (forces in equilibrium)

Name	Member	N [kN]	Vy [kN]	Vz [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	B1 / End	-41.0	-5.6	-25.6	100.0	-25.2	3.8
	B2 / End	41.0	5.6	-25.6	-100.0	25.2	3.8

Unbalanced forces

Name	X [kN]	Y [kN]	Z [kN]	Mx [kNm]	My [kNm]	Mz [kNm]
LE1	-81.9	-11.2	-51.2	200.0	-50.4	7.7

Check

Summary

Name	Value	Check status
Analysis	100.0%	OK
Plates	0.0 < 5.0%	OK
Loc. deformation	0.0 < 3%	OK
Bolts	98.6 < 100%	OK
Welds	0.0 < 100%	OK
Buckling	Not calculated	
GMNA	Not calculated	

Plates

Name	t_p [mm]	Loads	σ_{Ed} [MPa]	ε_{Pl} [%]	$\sigma_{c,Ed}$ [MPa]	Status
B1	16.0	LE1	350.2	0.0	0.0	OK
B2	16.0	LE1	342.4	0.0	0.0	OK
PP1a	20.0	LE1	261.1	0.0	33.0	OK
PP1b	20.0	LE1	269.5	0.0	33.0	OK

Design data

Material	f_y [MPa]	ε_{lim} [%]
S 355	355.0	5.0

Symbol explanation

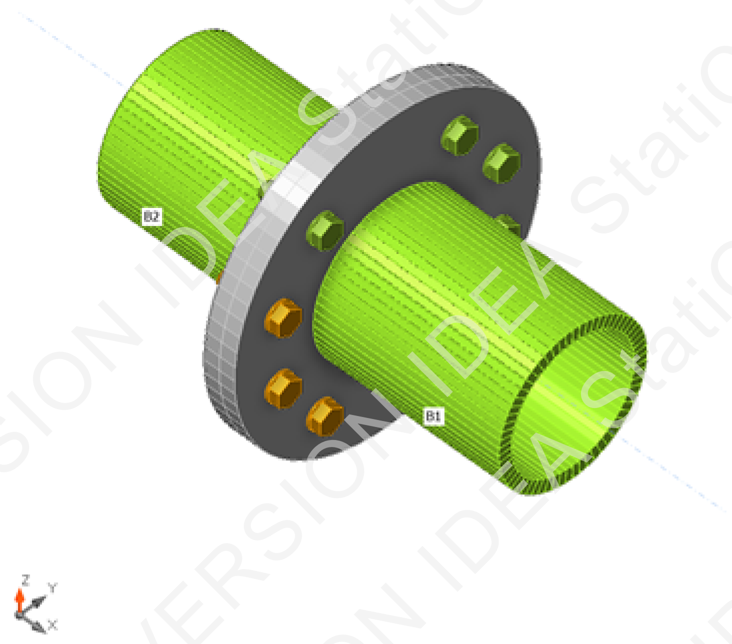
t_p	Plate thickness
σ_{Ed}	Equivalent stress
ε_{Pl}	Plastic strain
$\sigma_{c,Ed}$	Contact stress
f_y	Yield strength
ε_{lim}	Limit of plastic strain

Loc. deformation

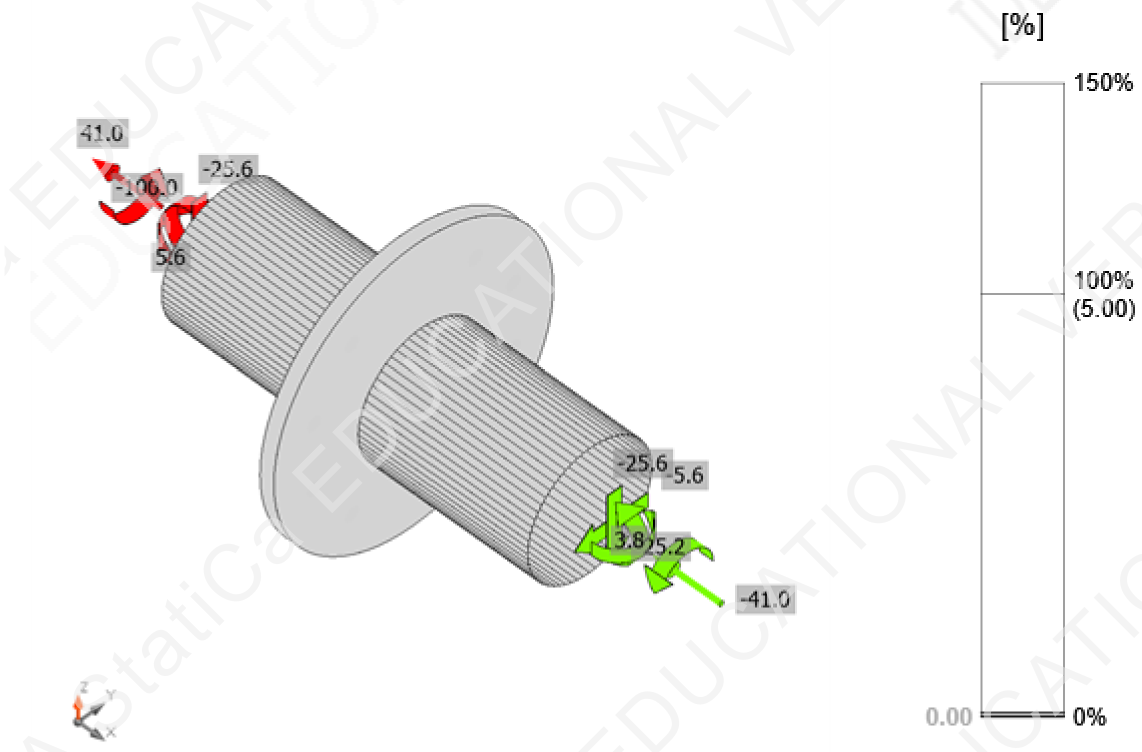
Name	d_0 [mm]	Loads	δ [mm]	δ_{lim} [mm]	δ/d_0 [%]	Check status
B1	194	LE1	0	6	0.0	OK
B2	194	LE1	0	6	0.0	OK

Symbol explanation

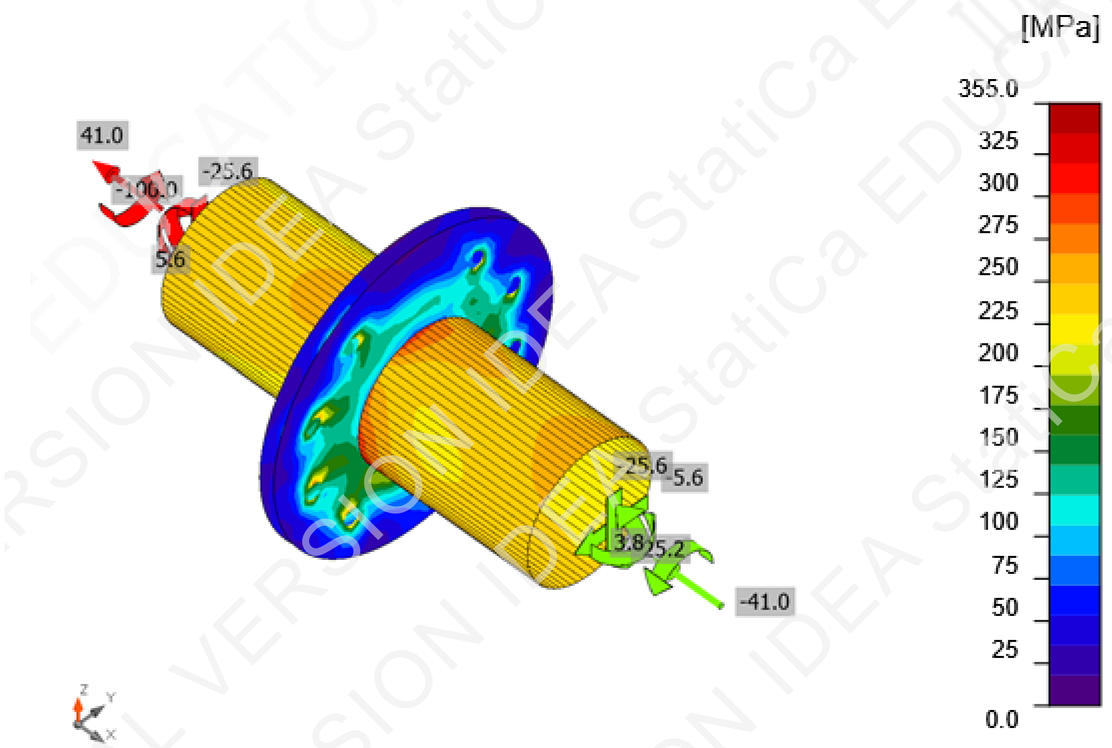
d_0	Cross-section size
δ	Local cross-section deformation
δ_{lim}	Allowed deformation



Overall check, LE1

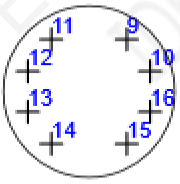


Strain check, LE1



Equivalent stress, LE1

Bolts

Shape	Item	Grade	Loads	$F_{t,Ed}$ [kN]	$F_{v,Ed}$ [kN]	$F_{b,Rd}$ [kN]	Ut_t [%]	Ut_s [%]	Ut_{ts} [%]	Detailing	Status
	B9	M20 10.9 - 1	LE1	0.3	83.4	392.0	0.2	85.1	85.2	OK	OK
	B10	M20 10.9 - 1	LE1	3.4	81.7	392.0	1.9	83.4	84.8	OK	OK
	B11	M20 10.9 - 1	LE1	0.0	89.1	392.0	0.0	90.9	90.9	OK	OK
	B12	M20 10.9 - 1	LE1	10.3	90.9	392.0	5.9	92.8	97.0	OK	OK
	B13	M20 10.9 - 1	LE1	30.9	84.4	392.0	17.5	86.1	98.6	OK	OK
	B14	M20 10.9 - 1	LE1	52.5	75.0	392.0	29.8	76.6	97.8	OK	OK
	B15	M20 10.9 - 1	LE1	49.1	76.4	392.0	27.8	78.0	97.9	OK	OK
	B16	M20 10.9 - 1	LE1	22.8	83.6	392.0	12.9	85.4	94.6	OK	OK

Design data

Grade	$F_{t,Rd}$ [kN]	$B_{p,Rd}$ [kN]	$F_{v,Rd}$ [kN]
M20 10.9 - 1	176.4	469.4	98.0

Symbol explanation

$F_{t,Ed}$	Tension force
$F_{v,Ed}$	Resultant of bolt shear forces Vy and Vz in shear planes
$F_{b,Rd}$	Plate bearing resistance EN 1993-1-8 – Tab. 3.4
Ut_t	Utilization in tension
Ut_s	Utilization in shear
Ut_{ts}	Interaction of tension and shear EN 1993-1-8 – Tab. 3.4
$F_{t,Rd}$	Bolt tension resistance EN 1993-1-8 – Tab. 3.4
$B_{p,Rd}$	Punching shear resistance EN 1993-1-8 – Tab. 3.4
$F_{v,Rd}$	Bolt shear resistance EN 1993-1-8 – Tab. 3.4

Welds

Item	Edge	T_w [mm]	L [mm]	Loads	$\sigma_{w,Ed}$ [MPa]	ε_{Pl} [%]	$\sigma_{\perp}$ [MPa]	$\tau_{\perp}$ [MPa]	$\tau_{\parallel}$ [MPa]	Ut [%]	Ut_c [%]	Detailing	Status
PP1a	B1-arc 1	-	558	-	-	-	-	-	-	-	-	OK	OK
PP1b	B2-arc 1	-	558	-	-	-	-	-	-	-	-	OK	OK

Design data

Material	f_u [MPa]	β_w [-]	$\sigma_{w,Rd}$ [MPa]	0.9 σ [MPa]
S 355	0.0	-	-	-

Symbol explanation

T_w	Throat thickness a
L	Length
$\sigma_{w,Ed}$	Equivalent stress
ε_{Pl}	Strain
$\sigma_{\perp}$	Perpendicular stress
$\tau_{\perp}$	Shear stress perpendicular to weld axis
$\tau_{\parallel}$	Shear stress parallel to weld axis
Ut	Utilization
Ut_c	Weld capacity estimation
f_u	Ultimate strength of weld
β_w	Correlation factor EN 1993-1-8 – Tab. 4.1
$\sigma_{w,Rd}$	Equivalent stress resistance
0.9 σ	Perpendicular stress resistance: 0.9*fu/γM2

Buckling

Buckling analysis was not calculated.

Code settings

Item	Value	Unit	Reference
Safety factor γ_{M0}	1.00	-	EN 1993-1-1 – 6.1
Safety factor γ_{M1}	1.00	-	EN 1993-1-1 – 6.1
Safety factor γ_{M2}	1.25	-	EN 1993-1-1 – 6.1
Safety factor γ_{M3}	1.25	-	EN 1993-1-8 – Table 2.1
Safety factor γ_C	1.50	-	EN 1992-1-1 – 2.4.2.4
Safety factor γ_{Inst}	1.20	-	EN 1992-4 – Table 4.1
Joint coefficient βj	0.67	-	EN 1993-1-8 – 6.2.5(7)
Effective area - influence of mesh size	0.10	-	
Friction coefficient - concrete	0.25	-	EN 1993-1-8
Friction coefficient in slip-resistance	0.30	-	EN 1993-1-8 – Table 3.7
Limit plastic strain	0.05	-	EN 1993-1-5
Detailing	Yes		
Distance between bolts [d0]	2.20	-	EN 1993-1-8 – Table 3.3
Distance between bolts and edge [d0]	1.20	-	EN 1993-1-8 – Table 3.3
Concrete breakout resistance check	Both		
Use calculated αb in bearing check.	Yes		EN 1993-1-8 – Table 3.4
Cracked concrete	Yes		EN 1992-4
Local deformation check	Yes		
Local deformation limit	0.03	-	CIDECT DG 1, 3 – 1.1
Geometrical nonlinearity (GMNA)	Yes		Analysis with large deformations for hollow section joints
Braced system	No		EN 1993-1-8 – 5.2.2.5

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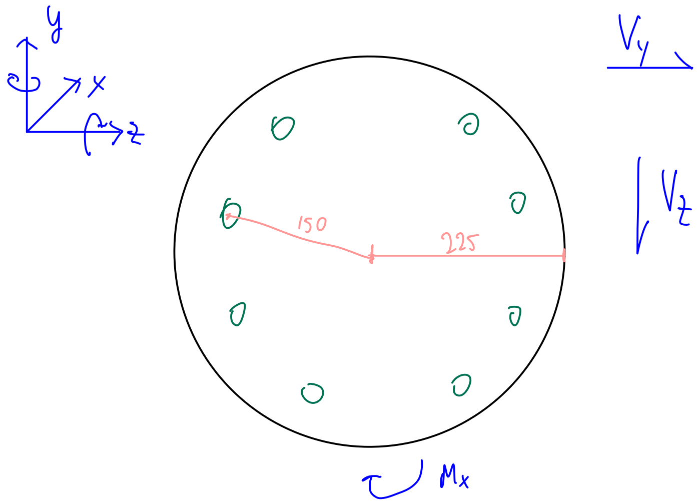
CALCULATION SHEET

Subject: Node with Cantilever Moment

Name: Matthew Rapa **Date:** 19/03/2024

$M_y = -25.19$ kNm
$M_z = 3.83$ kNm
$V_z = -25.63$ kN
$V_y = -5.63$ kN
$N = -40.97$ kN
Moment from cantilever ≈ 100 kNm
$f_y = 355$ N/mm²



Torsional Moment = 100 kNm (from cantilever)

$M_x = F \times p.d.$

$100 = 8(F) \times 0.150$

$F = 83.3$ kN / bolt

M20 8.8.

$F_{v,Rd} = 94.1$ kN

$\therefore \frac{83.3}{94.1} = 0.88$

Torsional Check OK **0.88**

$V_z = \frac{V}{8} = \frac{25.63}{8} = 3.204$ kN

$\frac{3.204}{94.1} = 0.034$

Shear Check OK **0.034**

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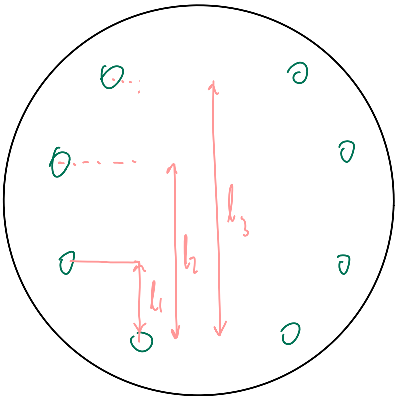
CALCULATION SHEET

Subject: Node with Cantilever Moment

Name: Matthew Rapa | **Date:** 19/03/2024

Assuming bottom bolts as centre of rotation

For M_y:



$l_1 = 0.075\,m$, $l_2 = 0.1677\,m$, $l_3 = 0.2427\,m$

(Autocad)

$$M_{y,Ed} = 2\left(\left(F_T * l_3\right) + \left(F_T * \frac{l_2^2}{l_3}\right) + \left(F_T \times \frac{l_1^2}{l_3}\right)\right)$$

$$25.19\ kNm = 2\left(0.2427 F_T + 0.1159 F_T + 0.0232 F_T\right)$$

$$25.19\ kNm = 0.7636\ F_T$$

$$F_T = 32.99\ kN/bolt$$

F_T M20 G 8.8 bolt = 141.1 kN

$$\frac{32.99}{141.1} = 0.234$$

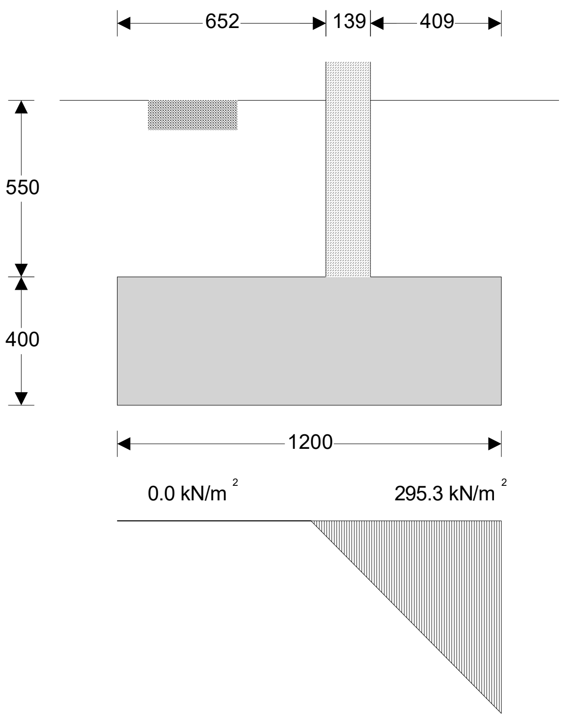
Bolts in Tension OK

0.234

Tedds	Project				Job no.	
	Calcs for				Start page no./Revision 1	
	Calcs by M	Calcs date 09/03/2025	Checked by	Checked date	Approved by	Approved date

STRIP FOOTING ANALYSIS AND DESIGN (BS8110-1:1997)

TEDDS calculation version 2.0.05.00



Strip footing details

Width of strip footing — $B = \mathbf{1200}$ mm

Depth of strip footing — $h = \mathbf{400}$ mm

Depth of soil over strip footing — $h_{soil} = \mathbf{550}$ mm

Density of concrete — $\rho_{conc} = \mathbf{23.6}$ kN/m^3

Load details

Load width — $b = \mathbf{139}$ mm

Load eccentricity — $e_P = \mathbf{121}$ mm

Soil details

Density of soil — $\rho_{soil} = \mathbf{25.0}$ kN/m^3

Design shear strength — $\phi' = \mathbf{25.0}$ deg

Design base friction — $\delta = \mathbf{31.0}$ deg

Allowable bearing pressure — $P_{bearing} = \mathbf{1500}$ kN/m^2

Axial loading on strip footing

Dead axial load — $P_G = \mathbf{60.0}$ kN/m

Imposed axial load — $P_Q = \mathbf{0.0}$ kN/m

Wind axial load — $P_W = \mathbf{0.0}$ kN/m

Total axial load — $P = \mathbf{60.0}$ kN/m

Foundation loads

Dead surcharge load — $F_{Gsur} = \mathbf{0.000}$ kN/m^2

Imposed surcharge load — $F_{Qsur} = \mathbf{0.000}$ kN/m^2

Strip footing self weight — $F_{swt} = h \times \rho_{conc} = \mathbf{9.440}$ kN/m^2

Soil self weight — $F_{soil} = h_{soil} \times \rho_{soil} = \mathbf{13.750}$ kN/m^2

Total foundation load $F = B \times (F_{Gsur} + F_{Qsur} + F_{swt} + F_{soil})$ = **27.8** kN/m

Horizontal loading on strip footing

Dead horizontal load H_G = **10.0** kN/m

Imposed horizontal load H_Q = **0.0** kN/m

Wind horizontal load H_W = **60.0** kN/m

Total horizontal load H = **70.0** kN/m

Check stability against sliding

Resistance to sliding due to base friction

$H_{friction} = \max([P_G + (F_{Gsur} + F_{swt} + F_{soil}) \times B], 0 \text{ kN/m}) \times \tan(\delta)$ = **52.8** kN/m

Passive pressure coefficient $K_p = (1 + \sin(\phi')) / (1 - \sin(\phi'))$ = **2.464**

Passive resistance of soil $H_{pas} = 0.5 \times K_p \times (h^2 + 2 \times h \times h_{soil}) \times \rho_{soil}$ = **18.5** kN/m

Total resistance to sliding $H_{res} = H_{friction} + H_{pas}$ = **71.3** kN/m

PASS - Resistance to sliding is greater than horizontal load

Check stability against overturning

Total overturning moment $M_{OT} = M + H \times h$ = **28.000** kNm/m

Restoring moment

Foundation loading $M_{sur} = B^2 \times (F_{Gsur} + F_{swt} + F_{soil}) / 2$ = **16.697** kNm/m

Axial loading on column $M_{axial} = (P_G) \times (B / 2 - e_P)$ = **28.716** kNm/m

Total restoring moment $M_{res} = M_{sur} + M_{axial}$ = **45.413** kNm/m

PASS - Restoring moment is greater than overturning moment

Calculate base reaction

Total base reaction $T = F + P$ = **87.8** kN/m

Eccentricity of base reaction in x $e_T = (P \times e_P + M + H \times h) / T$ = **402** mm

Base reaction acts outside of middle third of base

Calculate base pressures

q_1 = **0.000** kN/m^2

$q_2 = 4 \times T / [3 \times (B - 2 \times e_T)]$ = **295.329** kN/m^2

Minimum base pressure $q_{min} = \min(q_1, q_2)$ = **0.000** kN/m^2

Maximum base pressure $q_{max} = \max(q_1, q_2)$ = **295.329** kN/m^2

PASS - Maximum base pressure is less than allowable bearing pressure

Partial safety factors for loads

Partial safety factor for dead loads γ_{fG} = **1.00**

Partial safety factor for imposed loads γ_{fQ} = **1.00**

Partial safety factor for wind loads γ_{fW} = **1.00**

Ultimate axial loading

Ultimate axial loading $P_u = P_G \times \gamma_{fG} + P_Q \times \gamma_{fQ} + P_W \times \gamma_{fW}$ = **60.0** kN/m

Ultimate foundation loading

Ultimate foundation loading $F_u = B \times [(F_{Gsur} + F_{swt} + F_{soil}) \times \gamma_{fG} + F_{Qsur} \times \gamma_{fQ}]$ = **27.8** kN/m

Ultimate horizontal loading

Ultimate horizontal loading $H_u = H_G \times \gamma_{fG} + H_Q \times \gamma_{fQ} + H_W \times \gamma_{fW}$ = **70.0** kN/m

Ultimate moment on foundation

Ultimate moment $M_u = M_G \times \gamma_{fG} + M_Q \times \gamma_{fQ} + M_W \times \gamma_{fW}$ = **0.000** kNm/m

Calculate ultimate base reaction

Ultimate base reaction $T_u = F_u + P_u$ = **87.8** kN/m

Eccentricity of ultimate base reaction $e_{Tu} = (P_u \times e_P + M_u + H_u \times h) / T_u =$ **402** mm

Calculate ultimate pad base pressures

$q_{1u} =$ **0.000** kN/m^2

$q_{2u} = 4 \times T_u / [3 \times (B - 2 \times e_{Tu})] =$ **295.329** kN/m^2

Minimum ultimate base pressure $q_{minu} = \min(q_{1u}, q_{2u}) =$ **0.000** kN/m^2

Maximum ultimate base pressure $q_{maxu} = \max(q_{1u}, q_{2u}) =$ **295.329** kN/m^2

Calculate base lengths

Left hand length $B_L = B / 2 + e_P =$ **721** mm

Right hand length $B_R = B / 2 - e_P =$ **479** mm

Calculate rate of change of base pressure

Length of base reaction $B_x = 3 \times (B / 2 - e_{Tu}) =$ **595** mm

Rate of change of base pressure $C_x = (q_{2u} - q_{1u}) / B_x =$ **496.534** kN/m^2/m

Calculate ultimate moment

Ultimate moment $M_x = C_x \times (B_L - B + B_x)^3/6 - F_u \times B_L^2/(2 \times B) + H_u \times h =$ **22.096** kNm/m

Material details

Characteristic strength of concrete $f_{cu} =$ **40** N/mm^2

Characteristic strength of reinforcement $f_y =$ **500** N/mm^2

Characteristic strength of shear reinforcement $f_{yv} =$ **500** N/mm^2

Nominal cover to reinforcement $c_{nom} =$ **50** mm

Moment design

Diameter of tension reinforcement $\phi_B =$ **16** mm

Depth of tension reinforcement $d = h - c_{nom} - \phi_B / 2 =$ **342** mm

Design formula for rectangular beams (cl 3.4.4.4)

$K = M_x / (d^2 \times f_{cu}) =$ **0.005**

$K' = 0.156$

K < K' compression reinforcement is not required

Lever arm $z = d \times \min([0.5 + \sqrt{(0.25 - K / 0.9)}], 0.95) =$ **325** mm

Area of tension reinforcement required $A_{s\_req} = M_x / (0.87 \times f_y \times z) =$ **156** mm^2/m

Minimum area of tension reinforcement $A_{s\_min} = 0.0013 \times h =$ **520** mm^2/m

Tension reinforcement provided **16 dia. bars @ 200 centres bottom**

Area of tension reinforcement provided $A_{s\_B\_prov} = \pi \times \phi_B^2 / (4 \times s_B) =$ **1005** mm^2/m

PASS - Tension reinforcement provided exceeds tension reinforcement required

Calculate ultimate shear force at distance d from face of wall

Ultimate shear force at face of load $V_{su} = (q_{2u} - F_u / B) \times (B_R - b / 2 - d) - C_x \times (B_R - b / 2 - d)^2 / 2 =$ **17.143** kN/m

Shear stresses at distance d from face of wall (cl 3.5.5.2)

Design shear stress $v_{su} = V_{su} / d =$ **0.050** N/mm^2

From BS 8110:Part 1:1997 - Table 3.8

Design concrete shear stress $v_c =$ **0.511** N/mm^2

Allowable design shear stress $v_{max} = \min(0.8\text{N/mm}^2 \times \sqrt{(f_{cu} / 1 \text{ N/mm}^2)}, 5 \text{ N/mm}^2) =$ **5.000** N/mm^2

PASS - $v_{su} < v_c$ - No shear reinforcement required

	Project				Job no.	
Tedds	Calcs for				Start page no./Revision 4	
	Calcs by M	Calcs date 09/03/2025	Checked by	Checked date	Approved by	Approved date