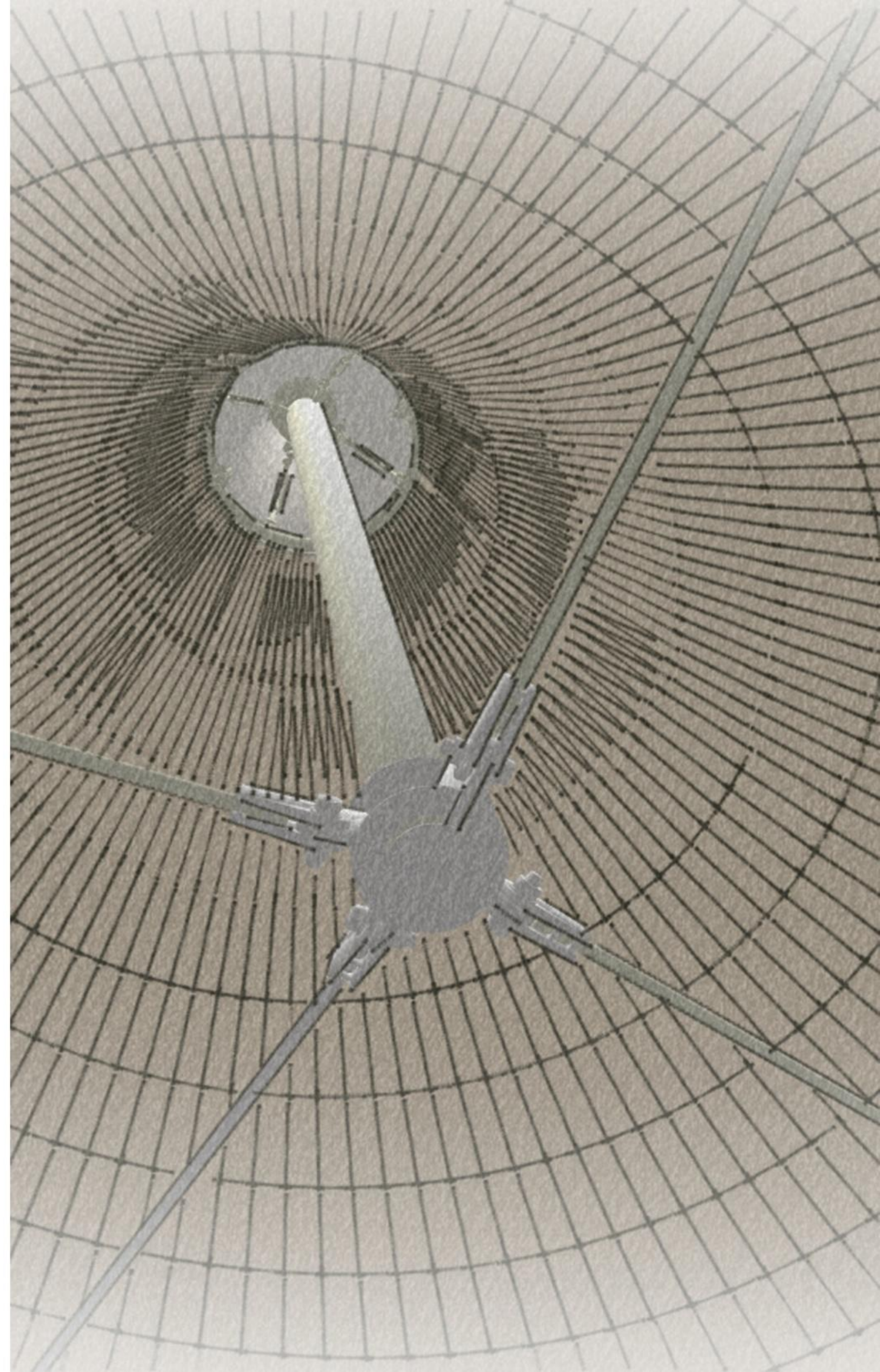
Institute of Membrane and Shell Technologies e. V.
Anhalt University of Applied Sciences
Dessau, Germany

Permanent Roof Cover For Traditional Restaurant in Koohsar Complex

Parisa Amirtash

March 2013



Permanent Roof Cover For Traditional Restaurant in Koohsar Complex

Master-Thesis

A thesis submitted in partial fulfillment
of the requirements for the degree of

Master Membrane Structures

submitted to

Anhalt University of Applied Sciences

Faculty of Architecture,
Facility Management and Geo Information

by

Parisa Amirtash
9th April 1985,TEHRAN,IRAN

Matrikel number: 4050238

Submission date: 15.03.2013

First Tutor: Prof. Dr. Ing. Robert Off
Second Tutor: Ing . Kourosh Shirani

Statement

I hereby declare that the work presented in this Master thesis, entitled

Permanent Membrane Roof Cover For Traditional Restaurant in Koohsar Complex

is entirely my own and that I did not use any sources or auxiliary means other than those referenced.

Tehran,Iran,07.03.2013 Parisa Amirtash

Index

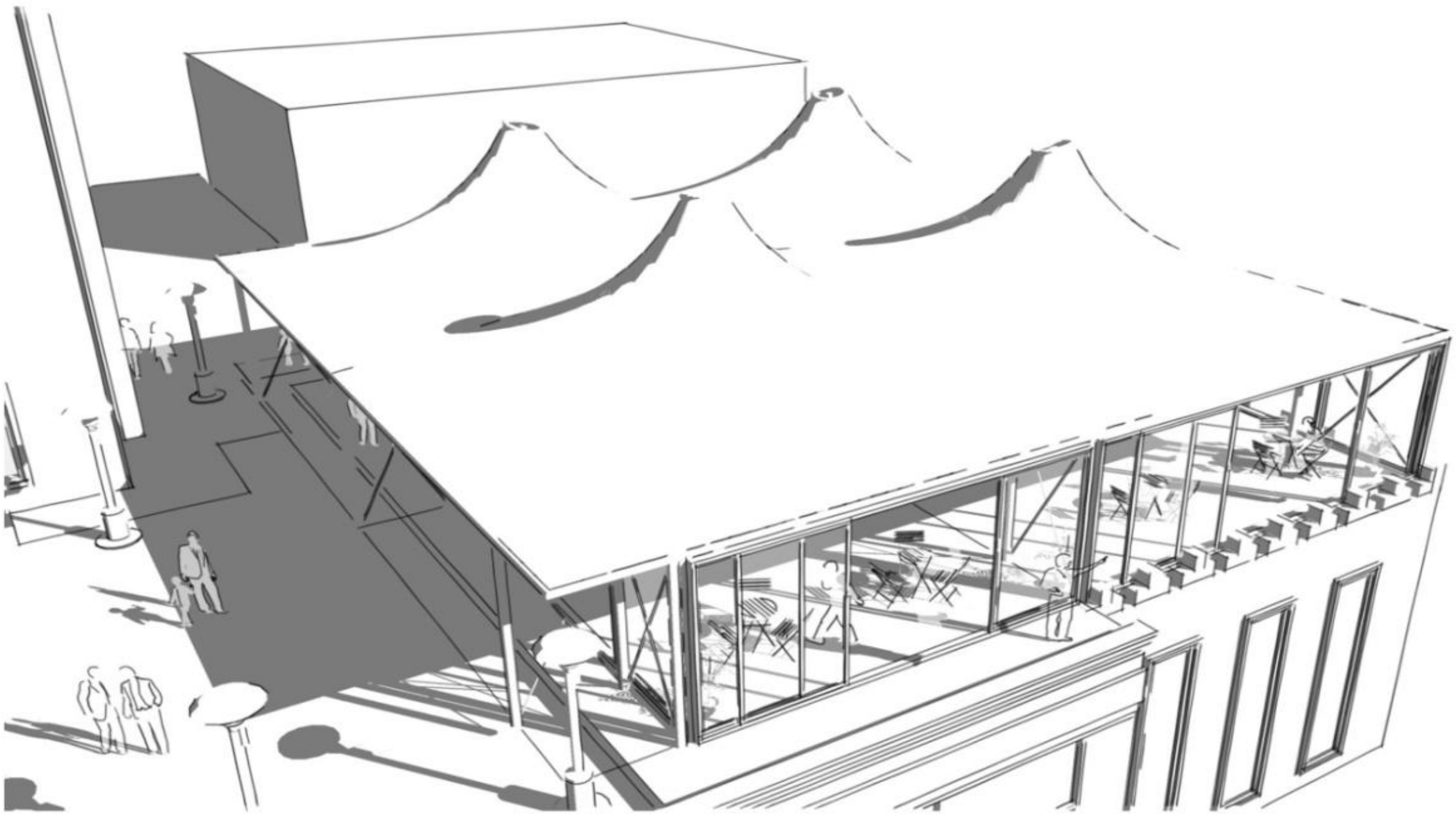
Image Index

Chapter 1 :

ARCHITECTURAL DESIGN

1-1 Preface

Koohsar project is a permanent roof for an open air traditional restaurant in Koohsar complex balcony.
Koohsar complex is a sport and cultural complex contains Bowling and Billiard Clubs and various types of restaurants and halls
In This Presentation I try to give a complete description of designing , manufacturing and installation process of Koohsar project from first step to the last.



1-2 Mashhad

Mashhad is the second largest city in Iran. It is located 850 kilometers (530 mi) east of Tehran, at the center of the Razavi Khorasan Province close to the of Afghanistan and Turkmenistan. Its population was 2,427,316 at the 2006 population census. It was a major oasis along the ancient Silk road connecting with Merv in the East.

In Arabic, the name Mashhad means the place of martyrdom the place where Imam Reza- the eighth Imam of Shia Muslims - was martyred and so his shrine was placed there.

Image 01 : IRAN

Image 02 : Razavi Khorasan Province

1-3 Geography and demographics

The city is located at 36.20º North latitude and 59.35º East longitude, in the valley of the Kashaf River near Turkmenistan, between the two mountain ranges of Binalood and Hezar-Masjed .The city benefits from the proximity of the mountains, having cool winters, pleasant springs, hot summers, and beautiful autumns.

The vast majority of the Mashhadi people are ethnic Persians who form over 95% of the city's population. Other ethnic groups include Kurdish and Turkmen people who have emigrated recently to the city from the North Khorasan province. The people of Mashhad who look like Asians are of Turkmen descent.

Mashhad is the hometown of some of the most significant Iranian literary figures and artists such as Mehdi Akhavan-Sales, the famous contemporary poet and Mohamad Reza-Shajarian the traditional Iranian singer and composer. Mashhad is also known as the city of Ferdowsi, the Iranian poet of Shahname, which is considered to be the national epic of Iran.

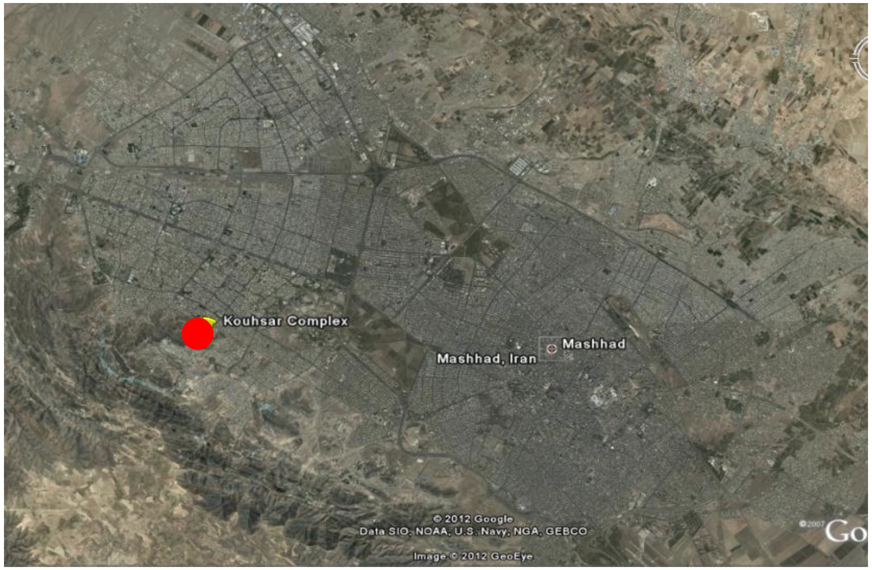


Image 03 : Mashhad City

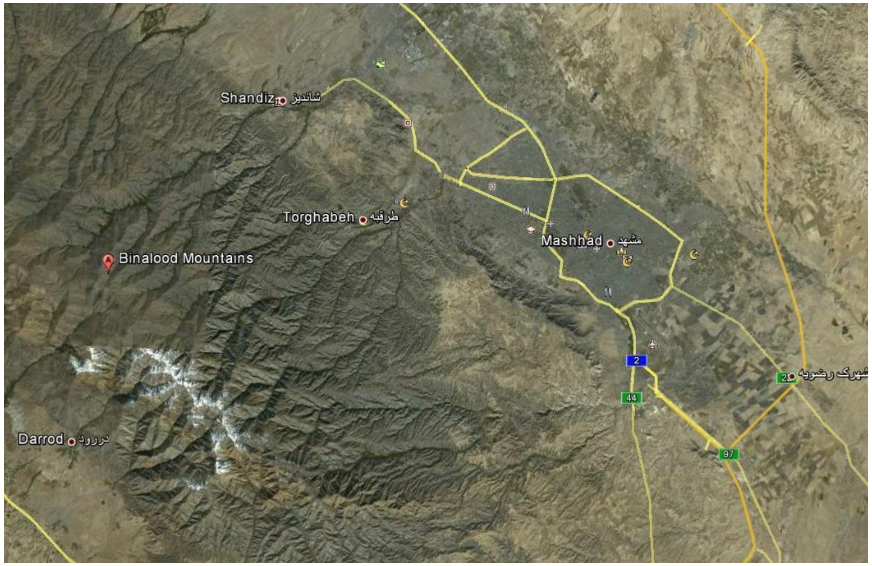


Image 04 : Mashhad

Image 05 : Koohsar Sport Complex And Cultural Tourism

1-4 Tourism

The second largest holy city in the world, Mashhad annually welcomes more than 32 million domestic pilgrims and more than a million pilgrims from abroad. Statistics shows that Since the holy temple of Imam Reza is located in Mashhad city, every Iranian visits Mashhad at least once in three years.

Apart from Imam Reza Shrine there is a number of large parks like Kooh Sangi park, Mellat Park , Koohestan Park-e-Shadi Complex within a Zoo. and the summer resorts at Torghabeh, Torogh, Zoshk, and Shandiz.

Mashhad also has some shopping malls that have modern attractions for tourists.

Some points of interest lie outside the city: the tomb of Khajeh Morad, along the road to Tehran; the tomb city where there are some inscriptions by the renowned Safavid calligrapher Reza Abbasi ; and the tomb of Khajeh Abasalt. Among the other sights are the tomb of the poet Ferdowsi in Tus.

Image 06 : Mashhad

1-5 Climate

Mashhad features a Steppe Climate with hot summers and cool winters. The city only sees about 250 mm of precipitation per year, some of which occasionally falls in the form of snow. Mashhad also has wetter and drier periods with the bulk of the annual precipitation falling between the months of December and May. Summers are typically hot and dry, with high temperatures sometimes exceeding 35 °C (95 °F). Winters are typically cool to cold and somewhat damper, with overnight lows routinely dropping below freezing. Mashhad enjoys on average just under 2900 hours of sunshine per year.
Prevailing wind direction in Mashhad is from south-east to north-west and the maximum wind speed is 90 km/hr. Here below you can see the map of Iran shows the snow load Basis in all provinces, Considering the map of snow load basis in Iran, Mashhad is located in places with up to 150 dKN/Sqm snow load.

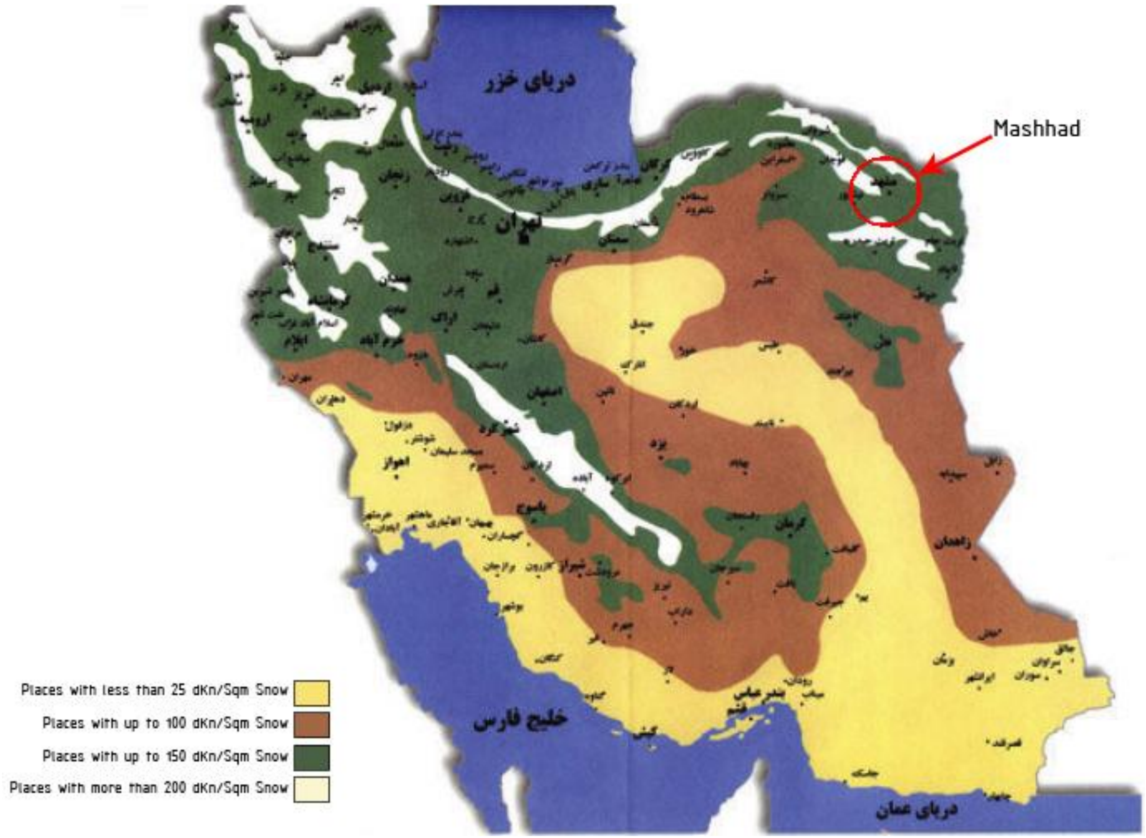
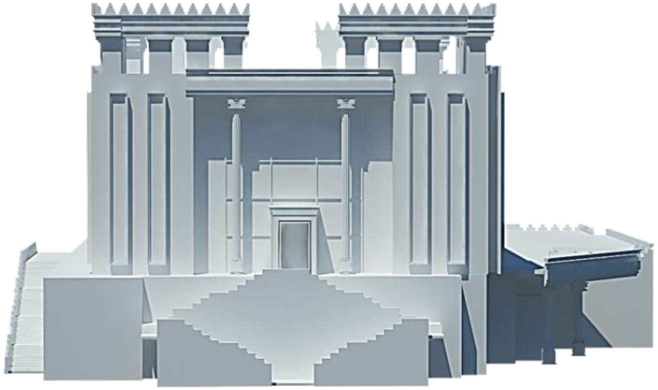


Image 07 : Snow Map

1-6 Koohsar Complex:

Koohsar Complex is located in west part of Mashhad city on top of Vakilabad Hills, which are the most important tourist places of Mashhad.
Koohsar Complex is one of a few deluxe sport and cultural complexes in Mashhad city, this complex contains some types of restaurants and coffee shops, deluxe saloons, Bowling and Billiard clubs....
This building is designed inspired by ancient Achaemenid architecture and specifically Perspolice palace in Shiraz which is one of the magnificent samples of Persian Architecture before Islam.
the Architect tried to design each elements of building face like columns and decorative Lithograph using motifs of Perspolice palace.

Image 08 : Membrane Structure Place On Building Terrace



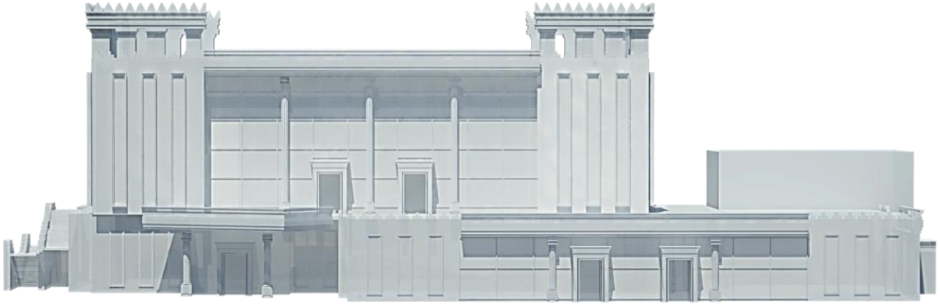


Image 09,10 : Building Elevations

Image 11 : Koohsar Complex,3D View

1-7 Persian Architecture :

Iranian architecture or Persian architecture has a continuous history from at least 5000 BCE to the present, with characteristic examples distributed over an area from Turkey and Iraq to Northern India and Tajikistan.
Iranian architecture is based on several fundamental characteristics. These are:

- structure
- homogeneous proportions
- anthropomorphism
- symmetry and anti-symmetry
- Introversion
- Minimalism

1-7-1 Geometry

Iranian architecture using pure forms such as circles and squares, and plans are based on often symmetrical layouts featuring rectangular courtyards and halls.

1-7-2 Design

Certain design elements of Persian architecture have persisted throughout the history of Iran. The most striking are a marked feeling for scale and a discerning use of simple and massive forms. The consistency of decorative preferences, the high-arched portal set within a recess, columns with bracket capitals, and recurrent types of plan and elevation can also be mentioned. Through the ages these elements have recurred in completely different types of buildings, constructed for various programs and under the patronage of a long succession of rulers.

1-7-3 Achaemenid Architecture

refers to the architectural achievements of the Achaemenid Persians manifesting in construction of spectacular cities used for governance and inhabitation (Perspolice, Susa, Ecbatana), temples made for worship and social gatherings ,and mausoleums erected in honor of fallen kings (such as the burial tomb of Cyrus the great). The quintessential feature of Persian architecture was its eclectic nature with elements of Median, Assyrian, and Asiatic Greek all incorporated. Achaemenid architecture is academically classified under Persian Architecture in terms of its style and design.
Achaemenid architectural heritage, beginning with the expansion of the empire around 550 B.C.E., was a period of artistic growth that left an extraordinary architectural legacy ranging from Cyrus the Great's solemn tomb in Pasargad to the splendid structures of the opulent city of Perspolice. With the advent of the second Persian empire, the Sassanid Dynasty(224-624 C.E.), revived Achaemenid tradition by construction of temples dedicated to fire, and monumental palaces.


Image 12 : Perspolice


Image 13 : Perspolice

1-8 Iranian Nomads:

Iran has one of the largest nomadic populations in the world, an estimated 1.5 million in a country of about 70 million.
The Bakhtiaris, who speak a Persian dialect known as Luri, are one of two main nomadic groups in Iran, along with the ethnic Turkic Qashqai group.
In April, when the desert heat begins to fire up, they will make the reverse trip to the cool, mountainous regions more than 100 miles to the north, crossing flood-swollen rivers and mountain passes to better grazing lands for their goats and sheep.

Image 14 : Nomadic Tents

1-8-1 Nomads Black Tents :

The black tent is used by nomadic groups that live in Mauritania, Morocco, Algeria, Tunisia, Egypt (Aulad 'Ali), Arabic countries, Europe (Gypsies), Turkey (Yuruks, Kurds), Iran, Afghanistan, Pakistan (Baluch), ... Most of the area belongs to an arid belt, characterized by a hot arid or semiarid climate. Accordingly, the requirements of the black tent are provision of shade and protection against wind, sand, and dust.

- The tent cover consists of woven strips, which are sewn together.
- The existence of black tents depends on animals that supply a suitable fiber. Goat hair is preferred because it has the necessary length and strength. The black color comes from the natural color of animal hair. The dark color of the tent cover provides good shade, which is needed in the heat of the deserts of Iran. Tent squares woven of light wool might even be dyed dark.
- Because the tent cover is very heavy, strong animals such as camels, dromedaries, or yaks are needed for transportation.
- The tent is a tensile form of construction. The tension and the heavy weight of the cloth are concentrated on a few vertical poles. The frame and cover are interdependent.

Image 15 : Nomadic Tent inside view

1-8-2 Location for tent pitching :

The factors that determine locations for tent pitching include tribal and administrative borders, governmental directives, protection against inclement weather, and the proximity of water. The tent is erected over the old fireplace, usually at the foot of a hill to provide shelter against wind, with the entrance facing down slope. If there is no suitable slope, the entrance of the tent is situated opposite the direction of the prevailing winds. The campground and hence the tent are likely to be located on a considerable incline. This helps prevent water from collecting inside the tent.

Image 16 : Location for tent pitching

1-8-3 Black tents production and erection :

Nomads can produce all components of the tent themselves. In most regions of the arid belt, goat hair is used to weave the cover of the black tent. To obtain the optimal length, nomads comb or pluck the hair. Thereafter, it is spun into yarn. The loom, used by nomadic women, determines the width (23-30 cm) of the tent squares, and their maximum length of 10-12 m determines the length of the tent. The loom is well adapted to nomadic mobility. When packed together, the unfinished weaving is not removed but easily rolled up with the loom .The woven tent squares are sewn together tightly. Sewing (not only of tents) is generally men's work.

The tent cover consists of 2 symmetric halves. The halves are held together with loops and toggles made of wood over a ridge pole. The seams run parallel to the ridge pole or they run across the ridge pole.

Two wooden prop poles, and sometimes 3, support the wooden ridge pole . To support the tent cover from inside, poles are situated under the first tent fold in the 4 corners. Zigzag ropes are simultaneously fixed under the roof. If there are no internal poles, a zigzag rope is indispensable. Both these ropes and the tension ropes are woven from goat wool from under the animal's belly. they rarely consist of other materials.

The tent cover hangs from tension ropes fixed at the first fold of the cover and supported by 2-m-high outer poles. They are pegged to the ground with wooden pins about 6 m away from the tent. There are 3-7 poles on each side and 1 or more at the back and the front .In addition, the tent is fixed downward from the second fold. If the second fold is higher than 1 m above ground, these tension ropes run above the poles as well. Otherwise, the ropes are pegged directly into the ground. The tent must be fixed firmly to the ground. During stormy weather, a family member often checks the pegging. The use of wood in tent construction is reduced to a minimum, and the prop poles are of great value. The tensile construction of the black tent is suitable for nomadic habitats above the tree line.

Image 17 : Nomadic Black Tents

Image 18 : Nomadic Black Tents

1-8-4 Protection against Sun light, rain and wind :

The weaving of the tent cover is so loose that it allows daylight to enter and smoke from the fireplace to escape. The cloth is "reasonably waterproof when new and becomes increasingly waterproofed with the oily cow-dung smoke soot. In addition, the natural lanolin content of the wool repels water. When the tent cover gets wet, the weave swells up, narrowing the meshes. However, if the rain lasts, the weave allows it to enter the tent. After the rain ceases, humidity evaporates quickly as a result of high insulation. One advantage of the loosely woven tent cloth is that it offers little susceptible surface to the heavy winds that frequently blow.

Image 19 : Nomadic Black Tents (Inside view)

1-9 Alternatives

1-9-1 ALT 01

First and simplest idea for this project was a single high point membrane, this form had enough protection and with only 9 columns in borders I could cover about 400sqm area, but this single highpoint for a very important and deluxe restaurant in Koohsar complex was not remarkable and exciting, and because it was a huge highpoint it would disturb the building's face.

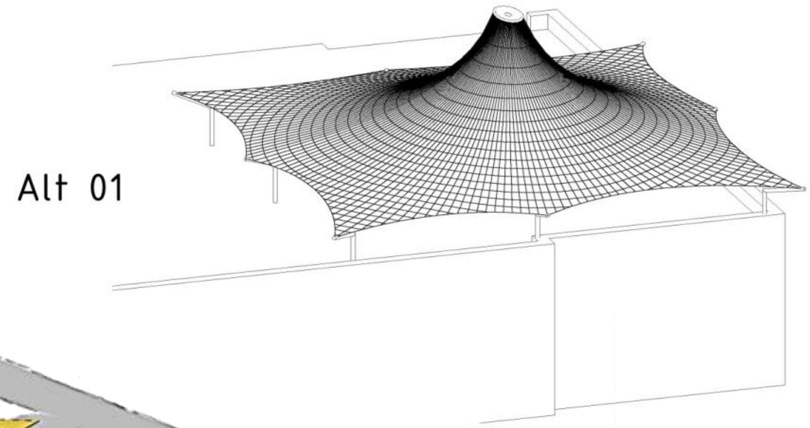


Image 20 : ALT01

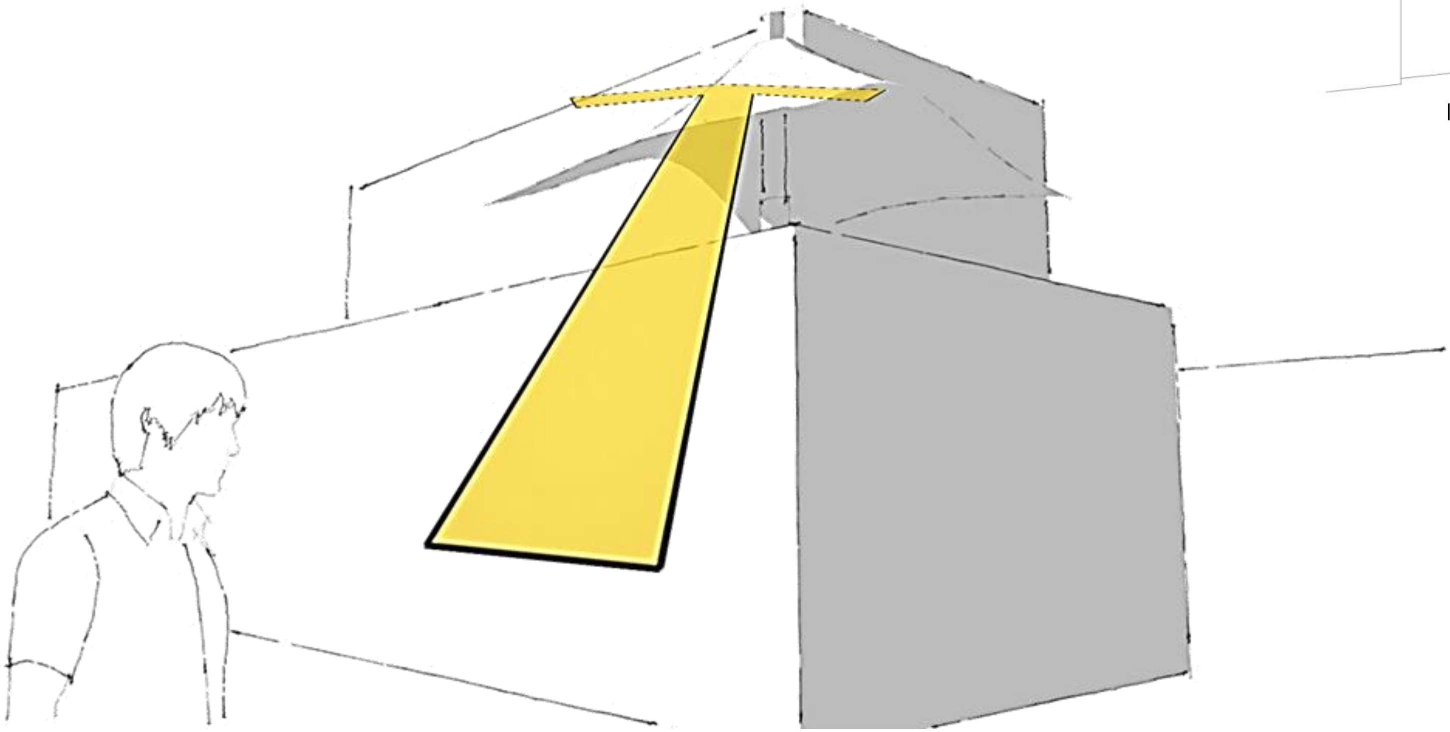


Image 21 : ALT01

1-9 Alternatives

1-9-2 ALT 02

Second alternative was an inverse highpoint (umbrella) it had only one column so it could provide a wide area without columns. it seemed more exciting but it didn't have enough protection against sun light, wind and rain.
One of the most important clients' requirements was the feasibility to close the space with glass walls but with this form it was so difficult and almost impossible, because the open sides were too high and we needed glass walls with over 5 meters height, so we forgot about this idea too.

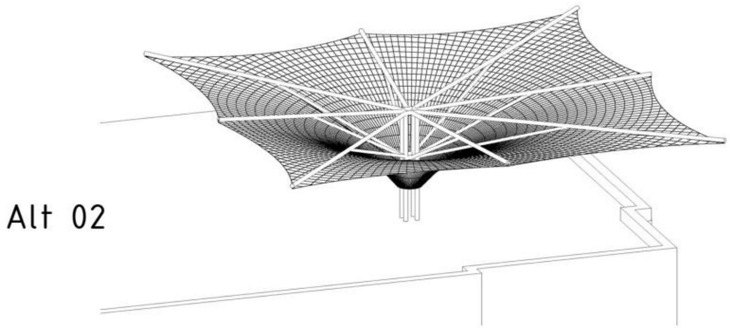


Image 22 : ALT02

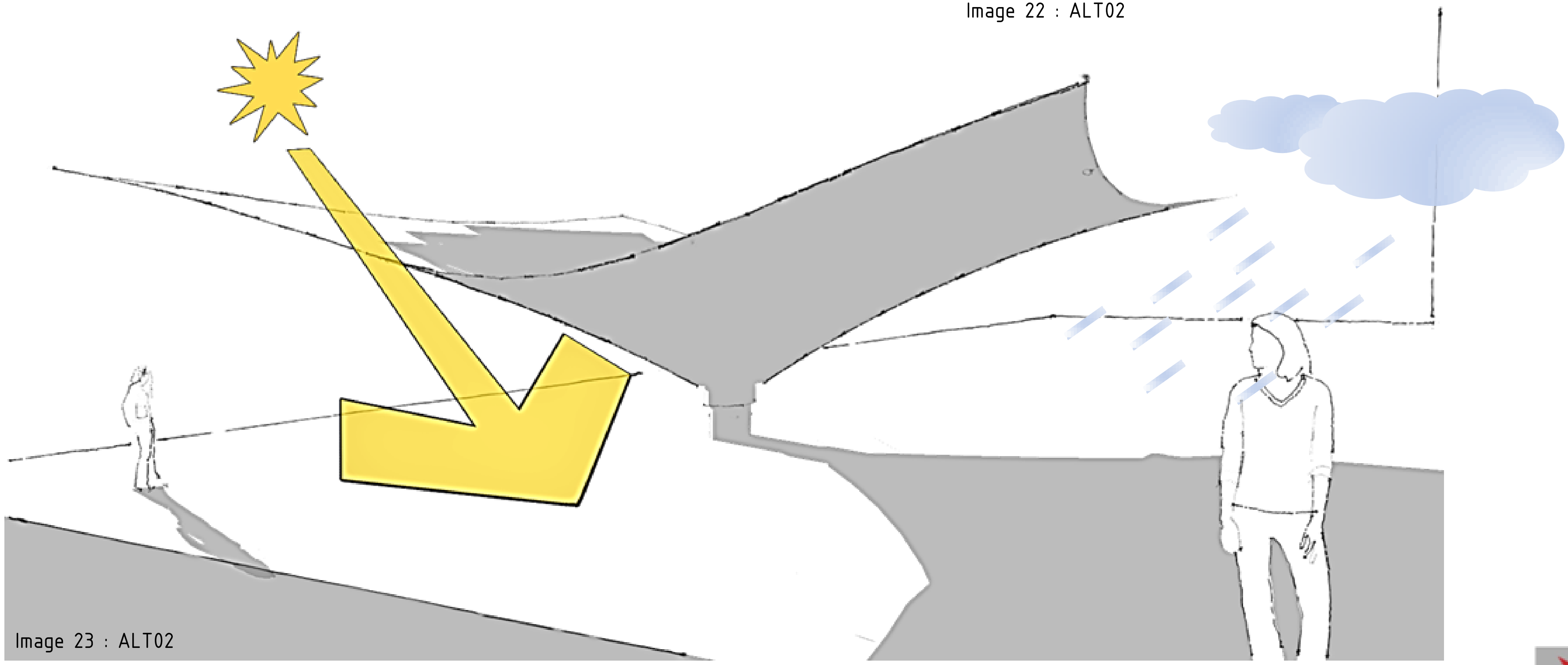


Image 23 : ALT02

1-9 Alternatives

1-9-3 ALT 03

Third alternative was very close to what I designed finally for this project, but it had some differences, it had curved edges that would reduce the coverage and it had 4 middle columns, in this way we had 13 columns that would interrupt the restaurant space in 4 places and also it had an important structural problems cause in those 4 points we didn't have any columns or beams in building structure and our columns should have lied on a 10cm thick concrete slab that seemed almost impossible. So I left this idea too.

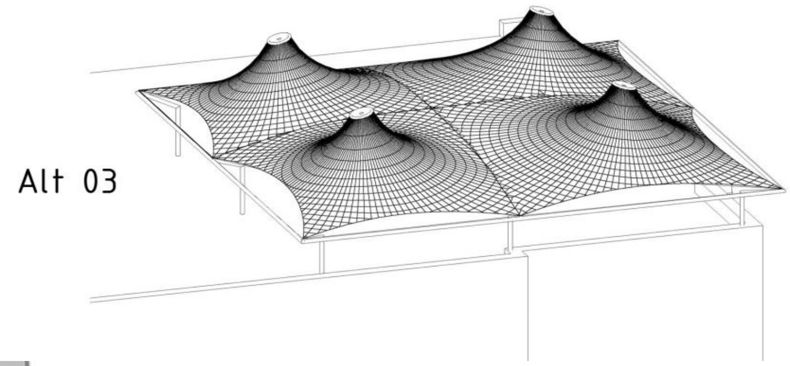


Image 24 : ALT03

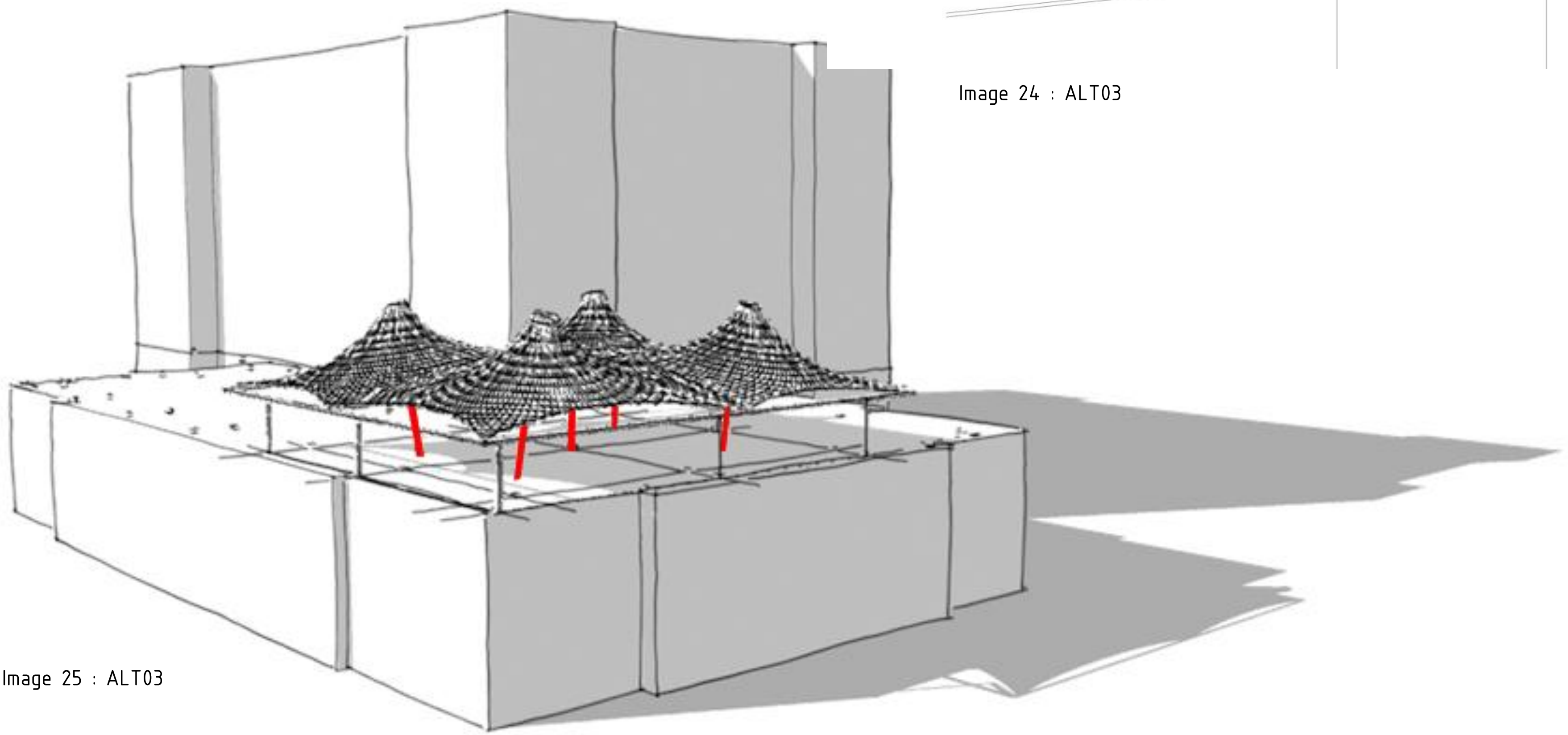


Image 25 : ALT03

1-9 Alternatives

1-9-4 ALT 04

Forth alternative was a great alternative for me, it could cover all requirements, it had only one column in the middle that was not very important , it's shape seemed exciting and it didn't disturb the building's face because it had a low height,and actually it was easy to close the space with glass walls, I thought that it can be my best choice for this project but after we calculated and analyzed the structure reactions and load we understood and the existing building can not bear this load, so I had to leave this idea too and think about it again.

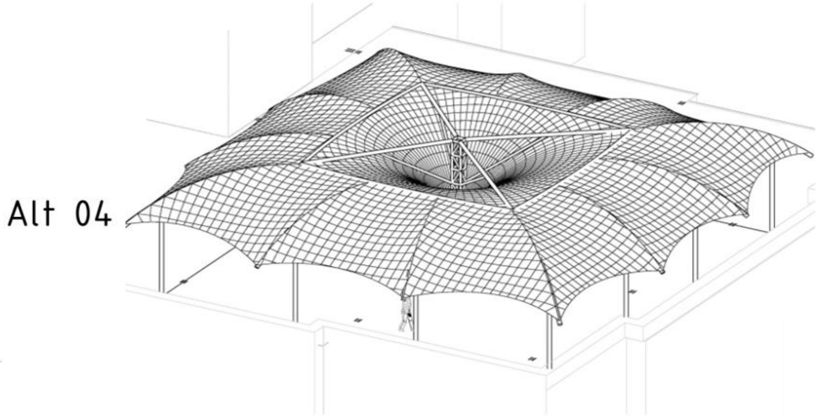


Image 26 : ALT04

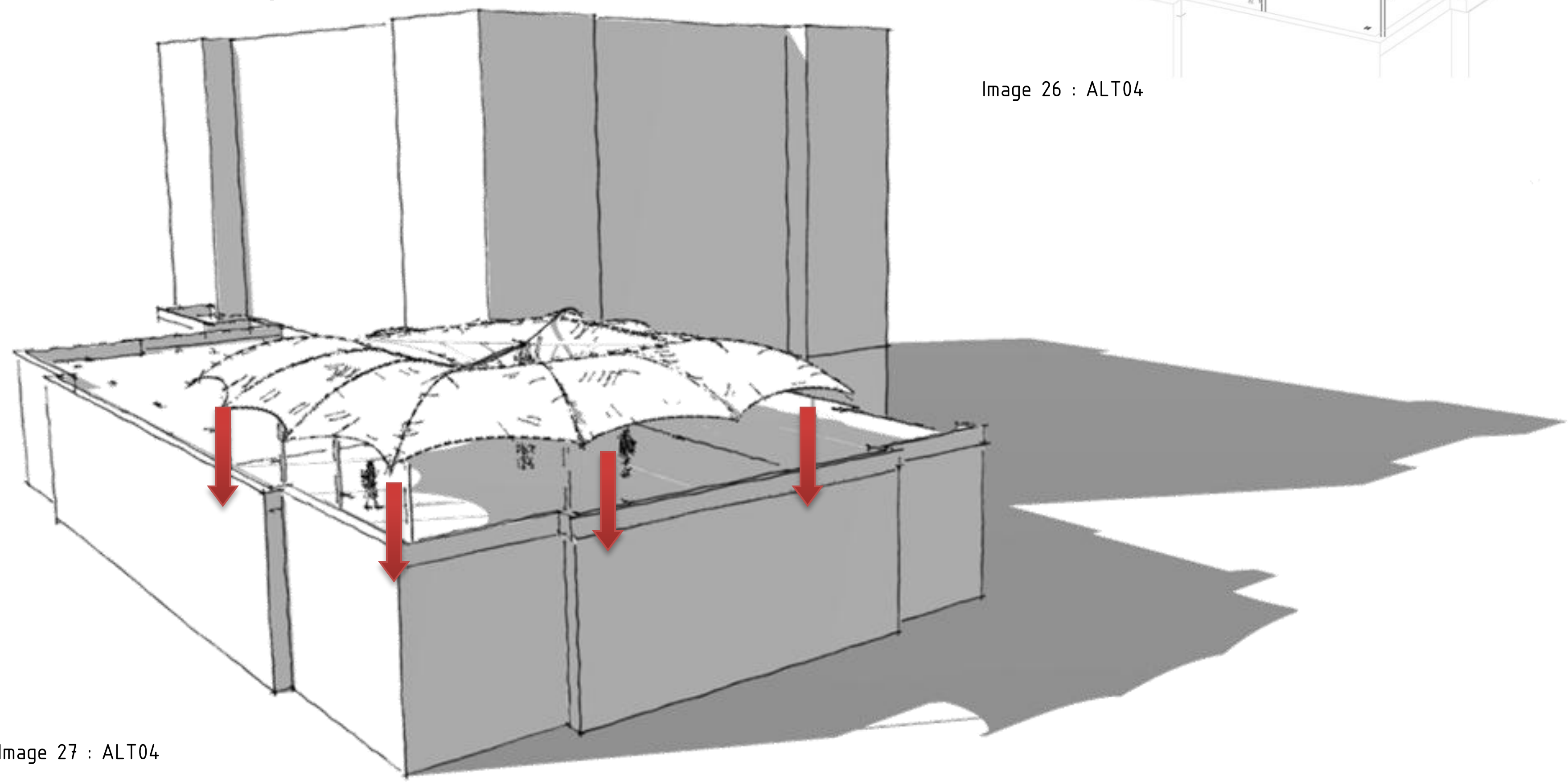


Image 27 : ALT04

1-10 Final Design

As I mentioned before the final alternative seems so close to the third one but it has some fundamental differences too, in this part I give an explanation about my ideas, design process and inspirations that finally lead to this form and shape of structure.

In primary steps there were some parameters to be considered. First of all was the function of the covered place as a traditional open air restaurant that must be active all year. Second parameter was the client's and his architectural consultant's requirements and taste, they determined dimensions of the coverage, location of it and they checked the relation between membrane structure and building's face. they wanted us to design the maximum coverage with minimum quantity of columns in middle space of restaurant to have as much integrated space as possible.

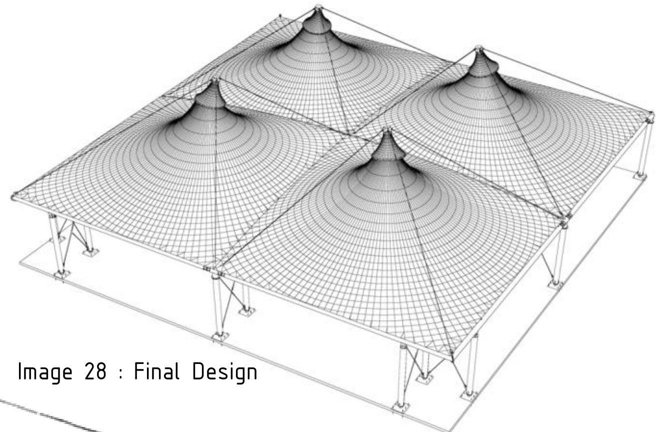


Image 28 : Final Design

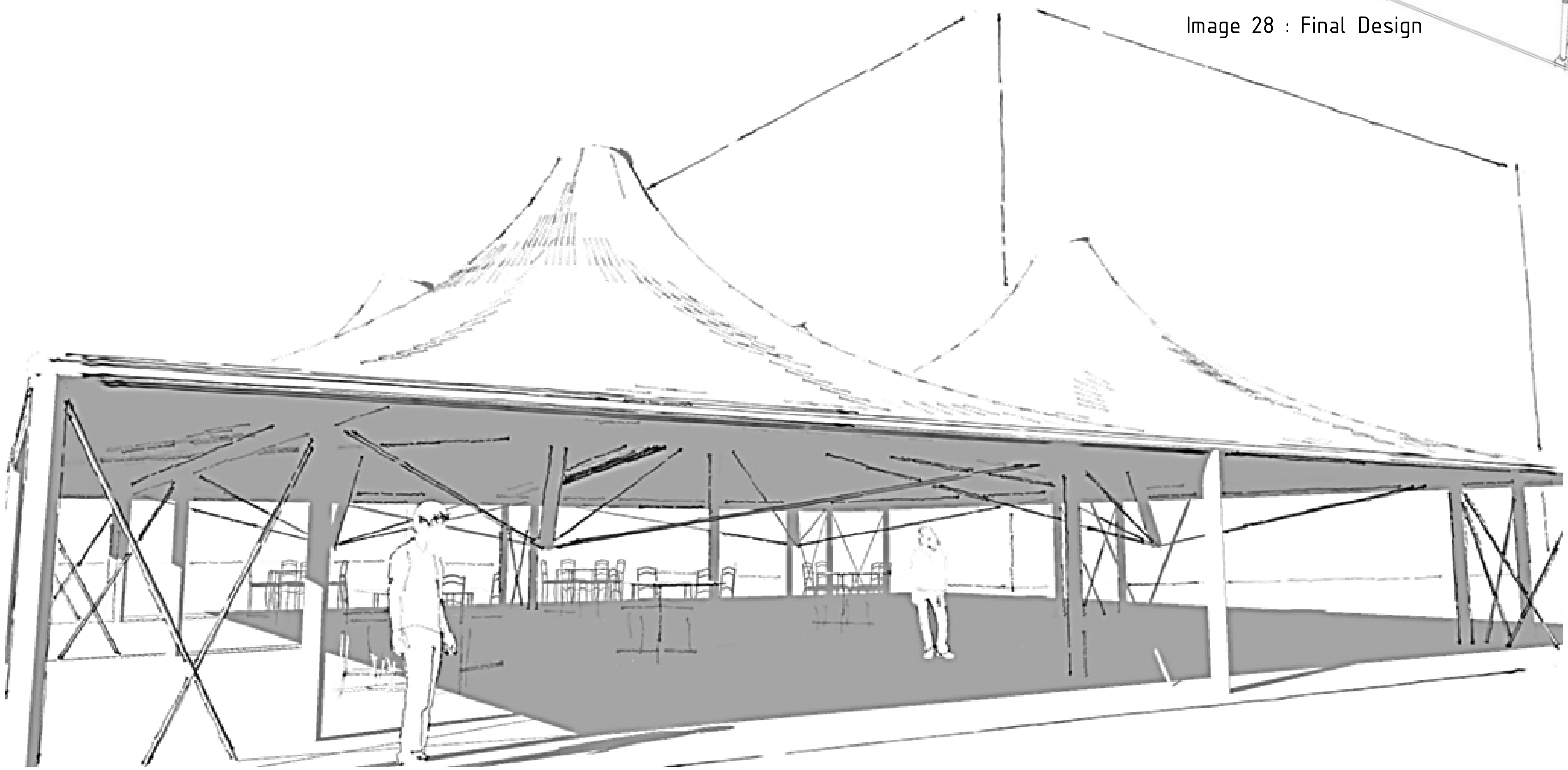


Image 29 : Final Design

1-10-1 Design Concept

Regarding that the Koohsar complex building is designed inspired by Iranian ancient architecture of Achaemenid Dynasty, I preferred to follow this concept and design the membrane structure on the balcony of this building inspired by Nomadic black tents which are the Iranian and some other Asian countries Nomads habitation for thousands of years (I gave a short introduction of nomadic black tents in previous chapter).So I purposed to design a kind of high point structure and to make it more exciting and reduce the height of it, I designed a combination of 4 cones that their main masts are a little inclined (it helped me to make them look more like nomadic tents).these 4 cones are arranged symmetric in two X and Y axes.

Image 30 : Koohsar Complex

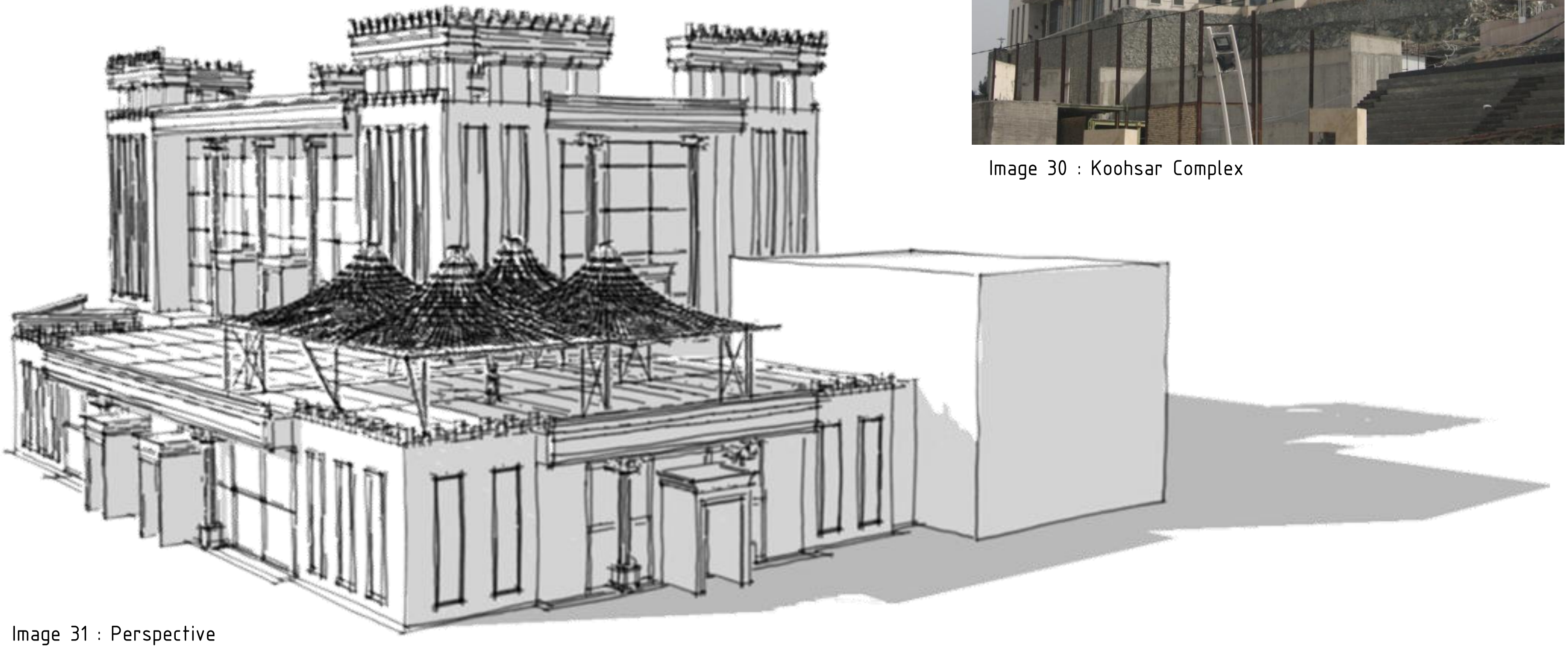


Image 31 : Perspective

1-10-2 Views and Walls

Koohsar complex is located on the highest hill in west part of Mashhad city (called Blvd Hashemieh) it has a very beautiful vision of the hole city and surrounded hills, in design process I considered not to disturb this beautiful vision, on the other hand I should have thought about structure air insulation, because in cold seasons we have to warp up the space with heaters and I decided to clamp the membrane and put glass walls in all 4 edges to be able to control the inside temperature in cold seasons, in this way i wouldn't disturb the beautiful vision of city in restaurant and I could keep the space warm.

Entrances of restaurant are located in north and west sides of structure along the balcony entrances in these two sides the glass walls are moved 1.85m inside the coverage to determine the entrance space, in east and south sides glass wall are placed on outer edge of structure to add spaces between columns to the restaurant.

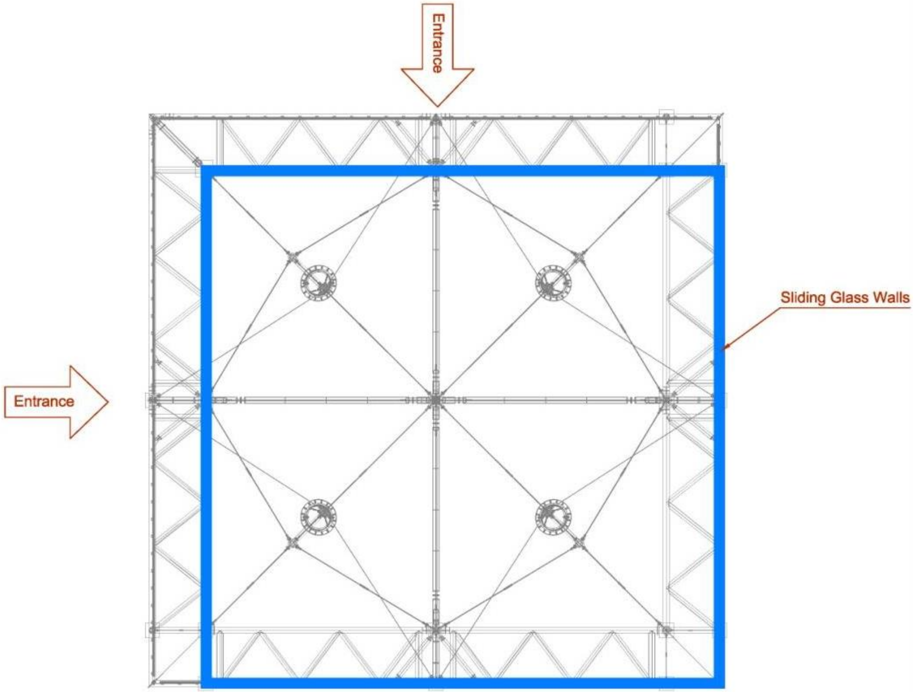


Image 32 : Glass Walls Diagram

Image 33 : Site Views

1-10-3 Fly-mast

For some reasons I designed this structure as a combination of 4 fly-mast cones :

1. At the center of each cone that I should have a mast, there weren't any columns in building structure to bear the main masts load.

2. I had to have minimum number of columns in middle area of restaurant; I just could have columns in edges of structure and only one in center.

3. The final reason was the exciting and high-tech look of fly-mast, it gives a sense of fly to the audiences.

Image 34 : Perspective

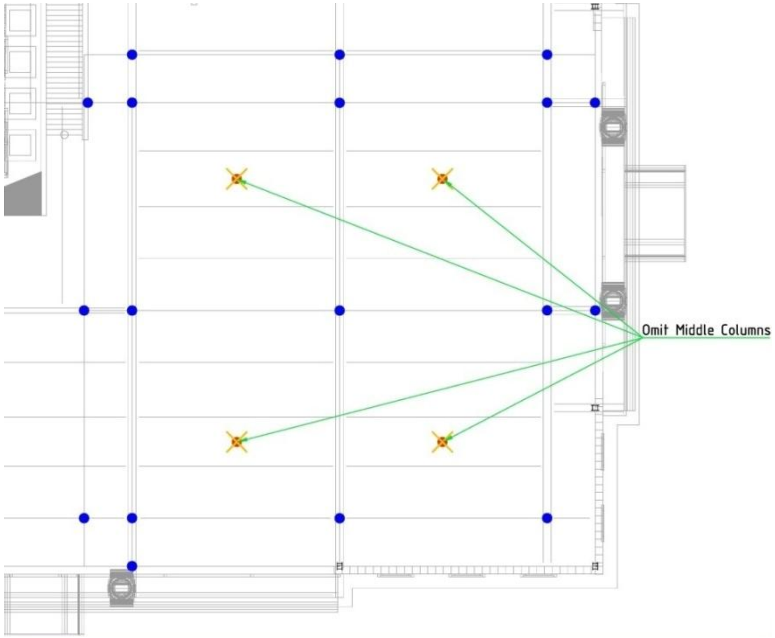


Image 35 : Columns Diagram

1-11 Perspective

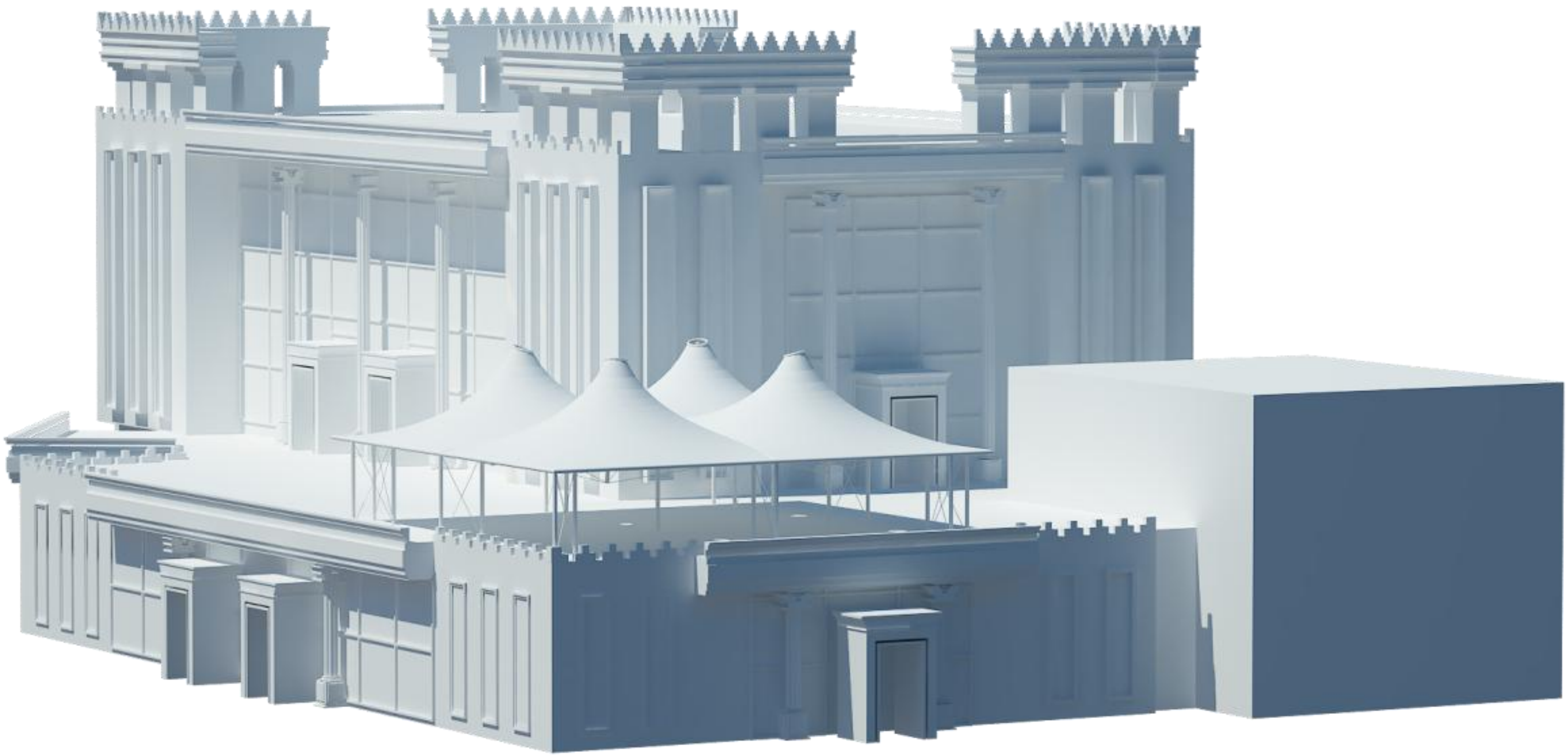


Image 36 : Perspective

1-11 Perspective

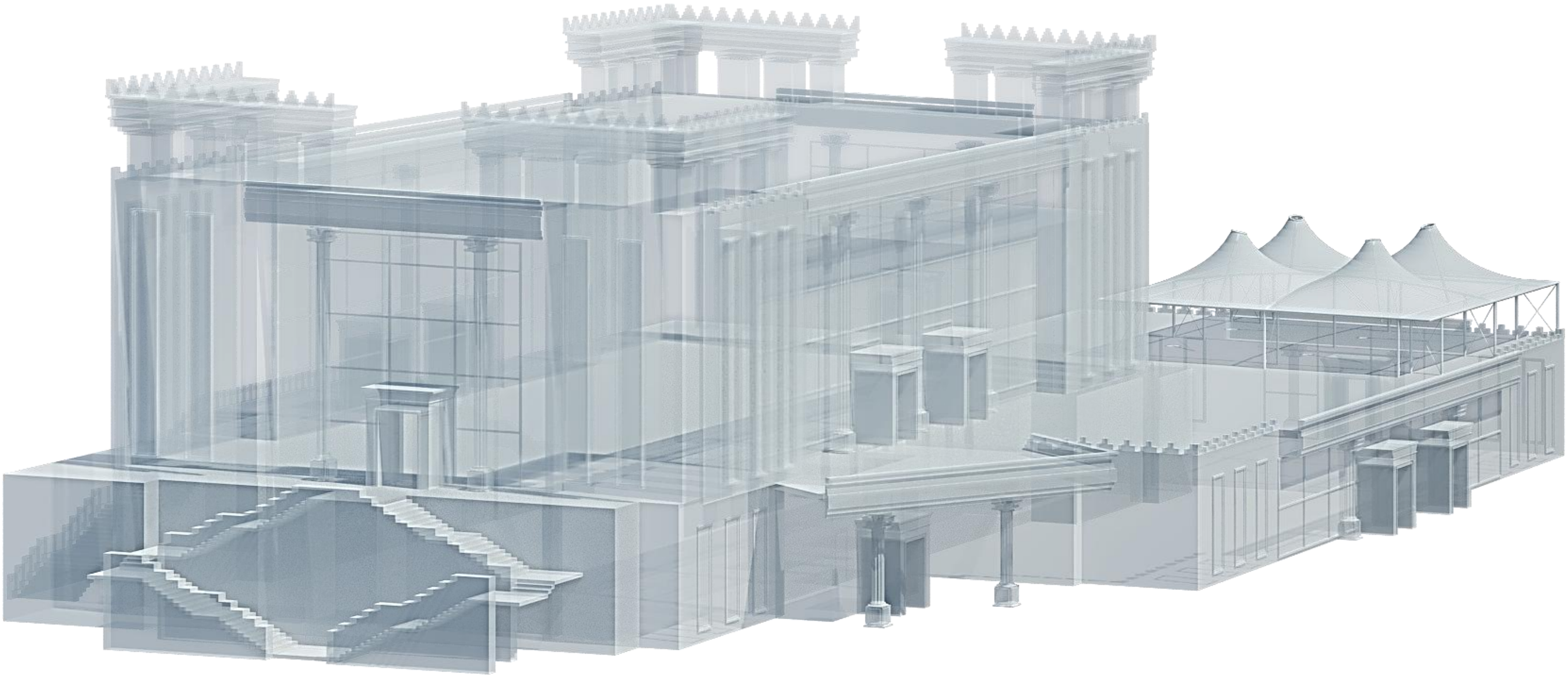


Image 37 : Perspective

1-11 Perspective

Image 38 : Perspective

Chapter 2 :

STRUCTURAL DESIGN

2-1 Structure -Design Concept:

In structural point of view, considered that the structure is placed on existing building that its beams and columns are designed and built before, we couldn't apply a huge load on them, so we should have designed a light weight structure and distribute the live and dead load uniformly on beams and columns to avoid centralizing the load. I Also designed a rigid truss frame, it is statically stable and I could apply fabric pretension and other live loads to this frame without imposing any tension or moment to building structure, so I should just have some columns (in this structure 20 columns) with rigid connection to the truss to transmit axial pressure forces to building structure.

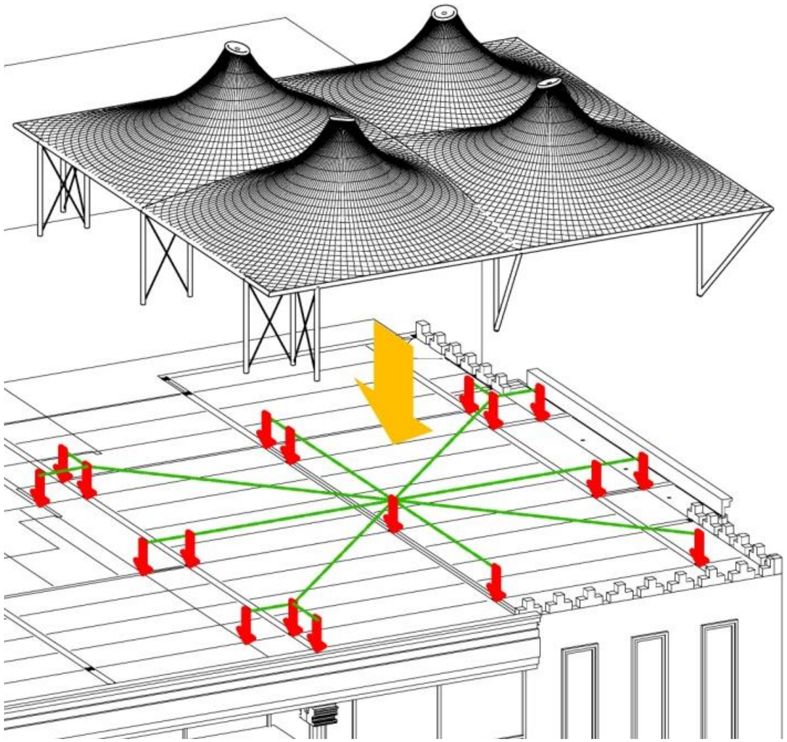


Image 39 : Distribute loads uniformly

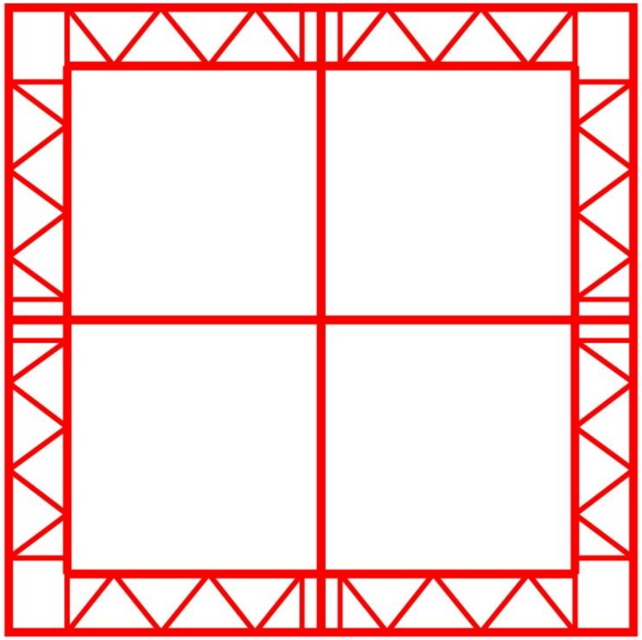
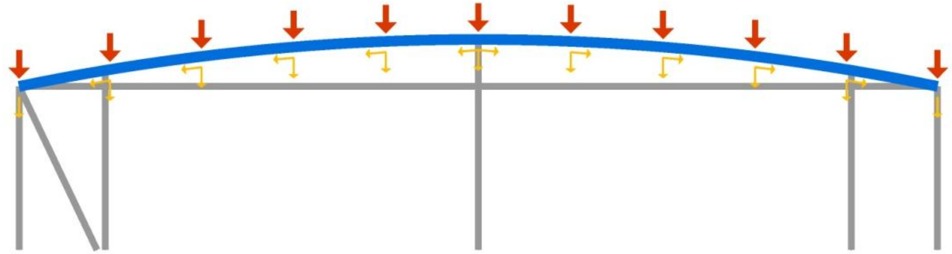


Image 40 : Rigid Truss Frame

2-1-1 Frame and trusses

Columns are working in twin groups with a cross cable bracing, this bracing is made each twin group as a truss, it helps bearing lateral loads like wind or maybe earthquake and also I could divide load in 18 base-points instead of 9 base-points. I also have two cross arch beams to divide structure to four symmetric squares, having arched beams helped in static stability by counterbalancing part of pressure loads and to avoid appearing any flat areas and ponding problems in the middle part of membrane between four cones.



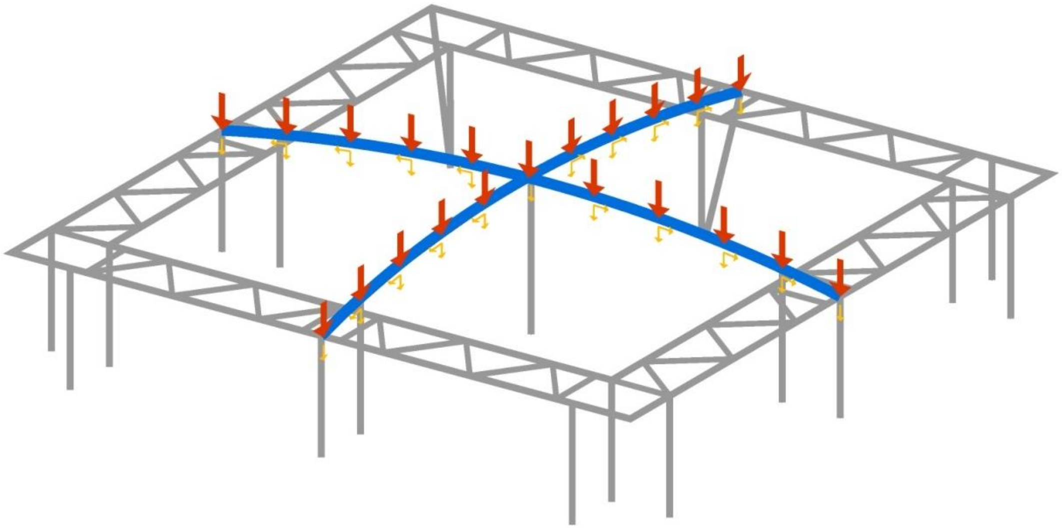


Image 41 : Arched Beams

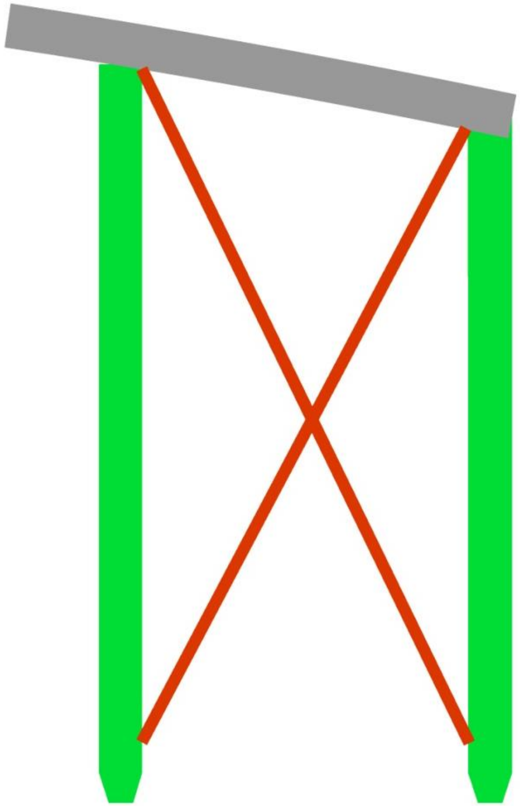


Image 42 : Twin Columns With Bracing

2-2 Node Reactions :

Here below it is possible to find the node numbers of reactions load:

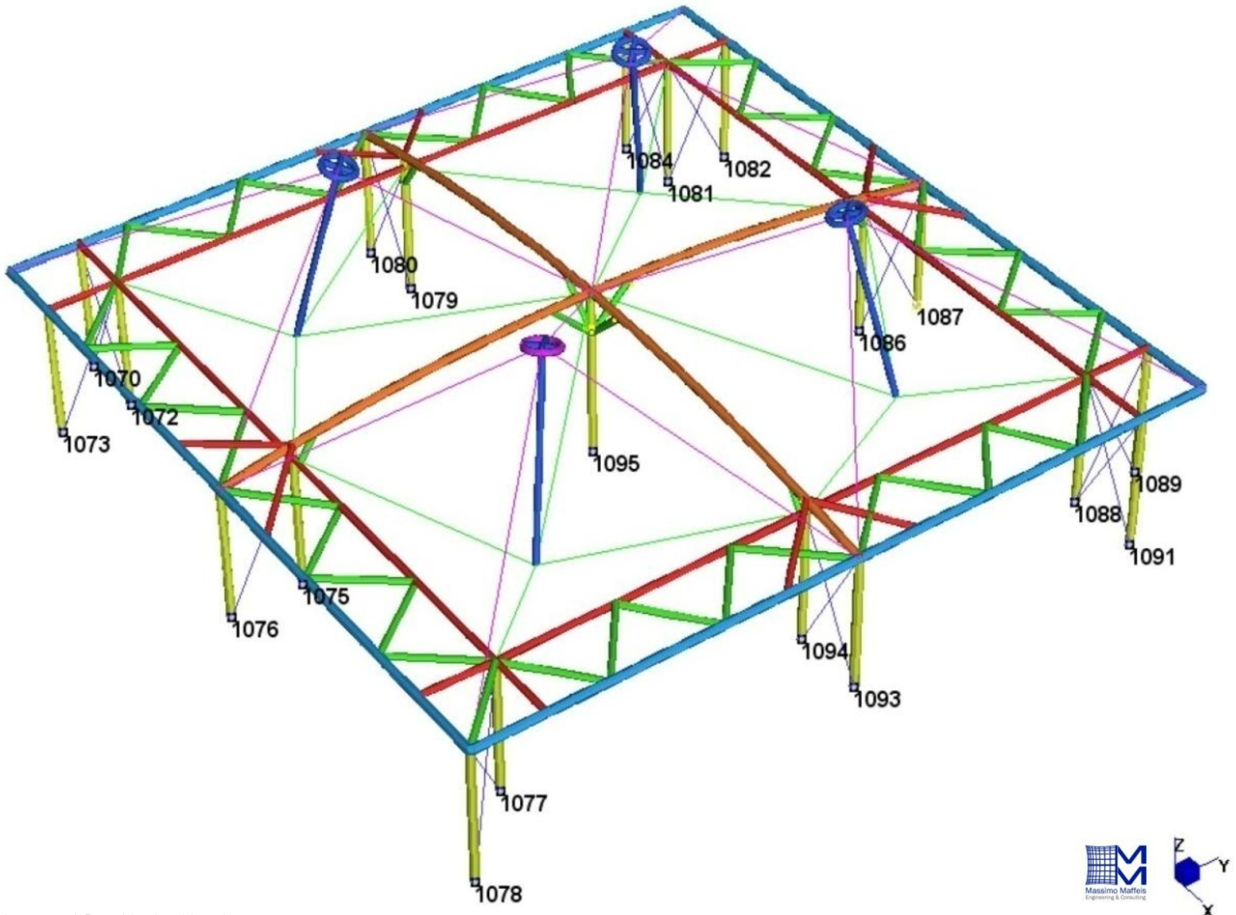


Image 43 : Node Numbers

On the table here below it is possible to find the node reactions:

Node	Combination	FX (kgf)	FY (kgf)	FZ (kgf)
1070:	1	-43	25	96
1070:	2	-207	30	-71
1070:	3	-203	31	-65
1070:	4	-465	-66	-2149
1070:	5	-2	-71	-1069
1070:	6	-107	-94	-1698
1070:	7	10	-154	-2150
1072:	1	39	38	775
1072:	2	3	5	3797
1072:	3	4	6	3752
1072:	4	-50	-18	2644
1072:	5	32	-20	1618
1072:	6	14	-56	2619
1072:	7	62	-48	216
1073:	1	25	-44	91
1073:	2	27	-179	4
1073:	3	28	-168	25
1073:	4	-93	-109	-1351
1073:	5	-61	-122	-1516
1073:	6	14	-390	-451
1073:	7	-130	-172	-2644
1075:	1	0	8	922
1075:	2	-2	-107	4469
1075:	3	-1	-29	5777
1075:	4	-32	-224	-235
1075:	5	-1	-218	-411
1075:	6	18	-312	-542
1075:	7	-25	-341	-4597
1076:	1	1	-54	224
1076:	2	2	-189	1553
1076:	3	3	-62	1752
1076:	4	-47	-448	-1446
1076:	5	-12	-377	-1516
1076:	6	24	-749	1054
1076:	7	-31	-651	-4158

Node	Combination	FX (kgf)	FY (kgf)	FZ (kgf)
1077:	1	-23	23	896
1077:	2	9	-10	3780
1077:	3	8	-8	3741
1077:	4	-81	62	327
1077:	5	1	42	799
1077:	6	-150	-149	1752
1077:	7	-50	44	-1819
1078:	1	45	-45	-17
1078:	2	172	-172	-78
1078:	3	161	-160	-57
1078:	4	111	-129	-1073
1078:	5	383	-347	-1690
1078:	6	242	-541	-1228
1078:	7	394	-403	-2589
1079:	1	10	1	919
1079:	2	-104	-3	4557
1079:	3	-29	-3	5892
1079:	4	-237	-14	489
1079:	5	-194	-12	-283
1079:	6	-215	-25	-398
1079:	7	-334	-25	-4940
1080:	1	-52	1	205
1080:	2	-190	2	1492
1080:	3	-79	3	1668
1080:	4	-704	0	-1188
1080:	5	-273	1	-399
1080:	6	-400	-17	-1408
1080:	7	-567	-9	-3624
1081:	1	39	-39	772
1081:	2	4	-5	3769
1081:	3	5	-4	3785
1081:	4	-42	18	2416
1081:	5	0	22	1719
1081:	6	-44	-126	1288
1081:	7	-21	-159	-271

Node	Combination	FX (kgf)	FY (kgf)	FZ (kgf)
1082:	1	25	43	95
1082:	2	30	181	-5
1082:	3	30	197	-42
1082:	4	-86	83	-1315
1082:	5	-66	119	-1532
1082:	6	-127	-34	-1806
1082:	7	-134	-48	-1903
1084:	1	-43	-25	96
1084:	2	-188	-29	-21
1084:	3	-186	-28	-20
1084:	4	-389	65	-1956
1084:	5	-32	70	-1161
1084:	6	-134	63	-1475
1084:	7	-80	121	-2519
1086:	1	-1	-10	925
1086:	2	1	106	4552
1086:	3	2	32	5932
1086:	4	-8	216	-517
1086:	5	18	222	-407
1086:	6	13	238	-1495
1086:	7	5	317	-5100
1087:	1	0	53	205
1087:	2	0	187	1487
1087:	3	0	99	1611
1087:	4	-16	342	-1071
1087:	5	11	414	-1427
1087:	6	1	275	-1877
1087:	7	0	449	-3621
1088:	1	-38	-39	775
1088:	2	-5	-4	3779
1088:	3	-6	-2	3821
1088:	4	-107	-16	1197
1088:	5	36	20	2288
1088:	6	43	-114	1279
1088:	7	-42	-175	-494

Node	Combination	FX (kgf)	FY (kgf)	FZ (kgf)
1089:	1	-25	43	95
1089:	2	-30	199	-46
1089:	3	-30	223	-99
1089:	4	53	31	-1168
1089:	5	86	139	-1594
1089:	6	125	-33	-1880
1089:	7	127	-50	-1931
1091:	1	44	-25	91
1091:	2	177	-27	-1
1091:	3	181	-25	-12
1091:	4	-26	60	-849
1091:	5	272	68	-1683
1091:	6	103	59	-1377
1091:	7	13	113	-2268
1093:	1	54	-2	223
1093:	2	183	-3	1568
1093:	3	84	-1	1725
1093:	4	139	11	-142
1093:	5	558	23	-1096
1093:	6	373	31	-1635
1093:	7	559	30	-3895
1094:	1	-8	-1	920
1094:	2	105	3	4464
1094:	3	31	5	5816
1094:	4	134	12	-590
1094:	5	222	22	306
1094:	6	212	24	-357
1094:	7	332	11	-4786
1095:	1	0	0	598
1095:	2	-2	1	11977
1095:	3	-1	2	15874
1095:	4	-27	-7	-1979
1095:	5	12	2	-1986
1095:	6	0	-14	-3407
1095:	7	0	-7	-16866

2-3 Materials

Steel Pipes and plates : Steel S235 / EN 10025

Yeild Tensile Strength	Fy = 2350 kg/cm^2
Ultimate Tensile Strength	Ft = 3600 kg/cm^2
Admissible Tensile strength	Fu = 1600 kg/cm^2
Elastic Module	E = 210000 N/mm^2

Bars-Bolts- Nuts-Washers : Steel Grade 8.8

Yeld tensile strength	fyk = 6400 daN/cm2;
Ultimate tensile strength	ftk = 8000 daN/cm2;
Admissible tensile strength:	sa = 3730 daN/cm2;

2-4 Structure Hand Sketch

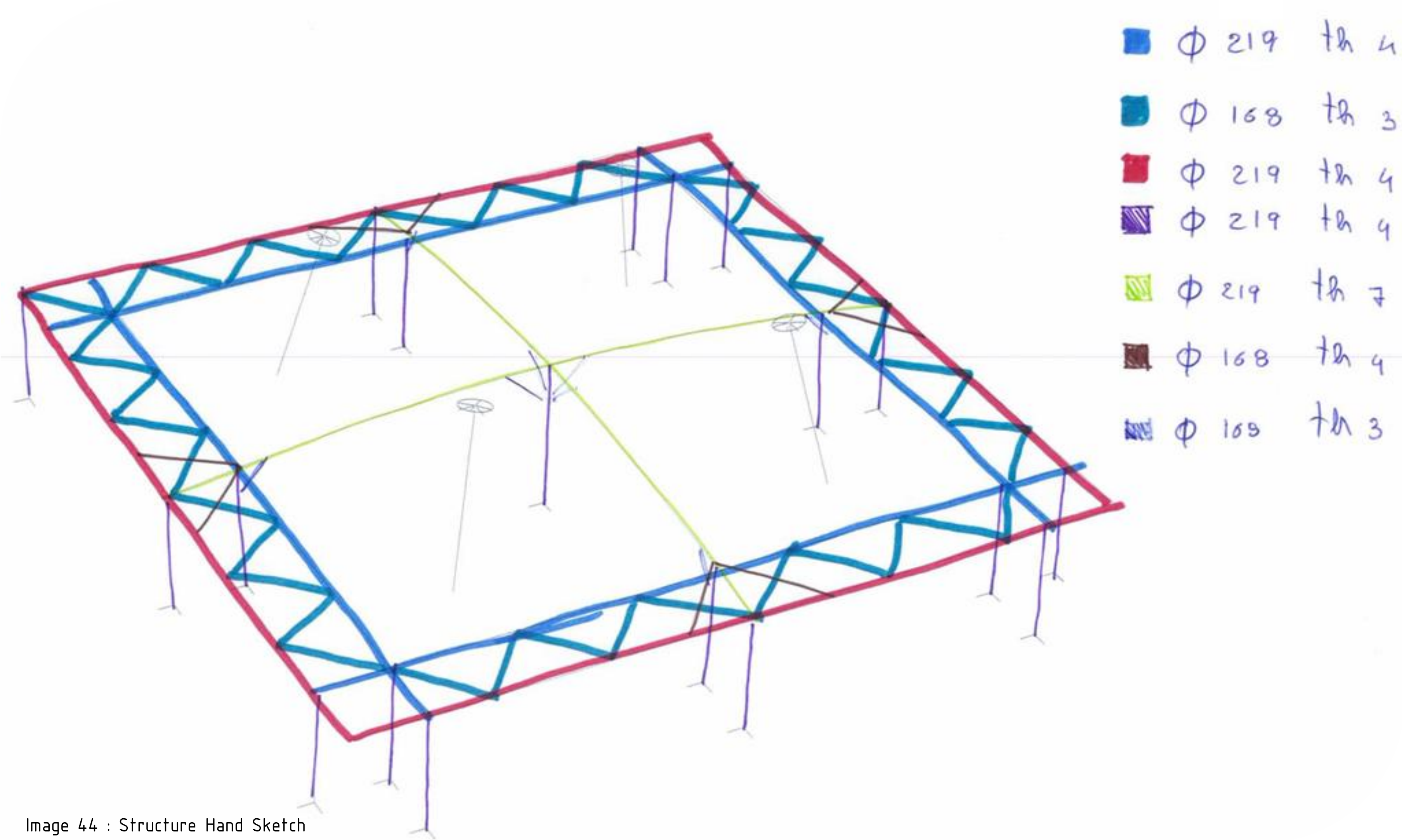


Image 44 : Structure Hand Sketch

2-5 Steel Structure Design :

From the pictures below it is possible to see the main steel elements.

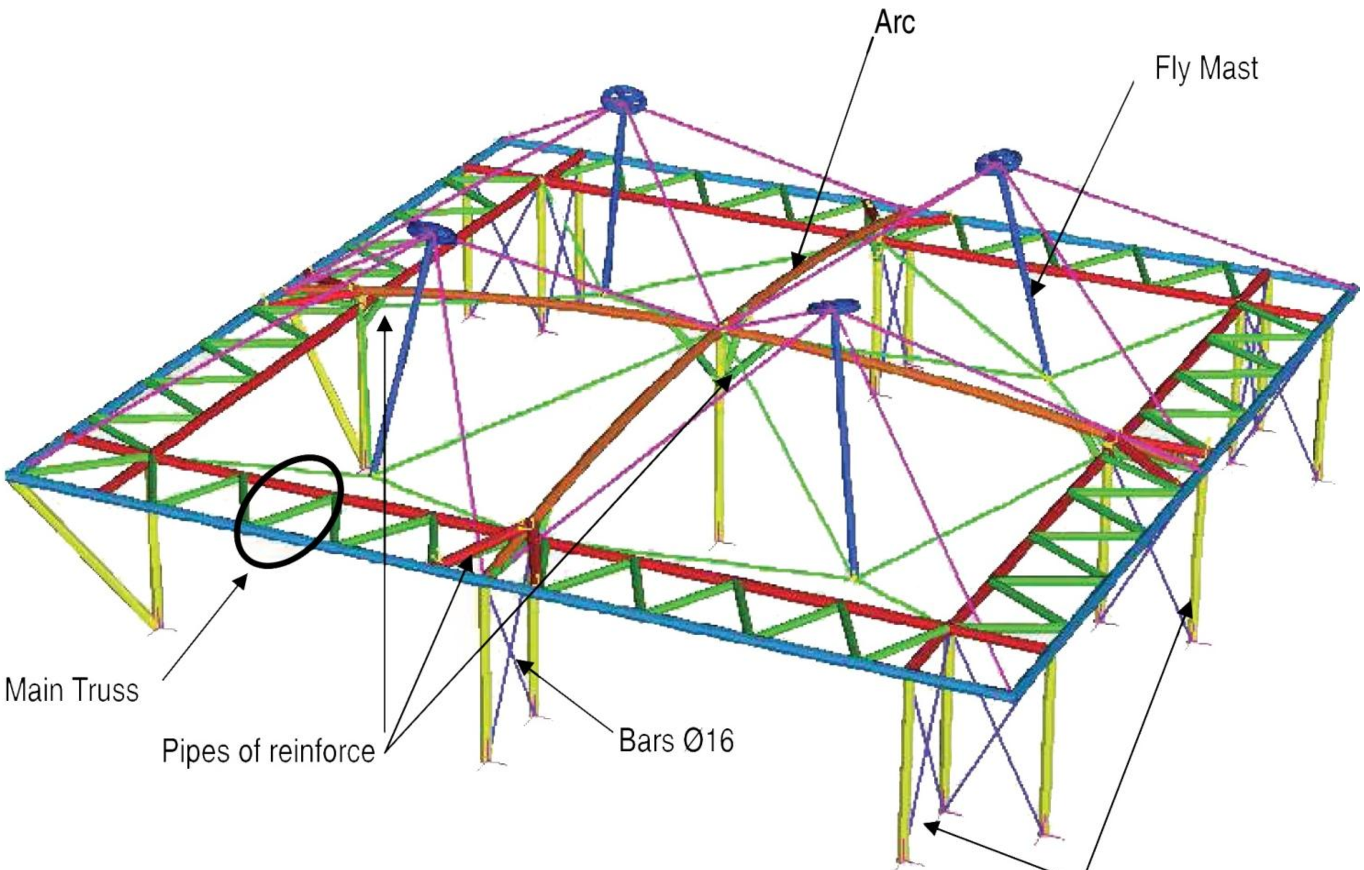


Image 45 : Structure Elements

2-5-1 Main Truss

From the pictures below it is possible to see the pipes on the main truss of structure

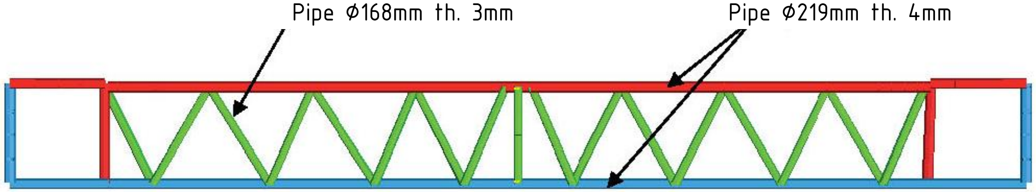
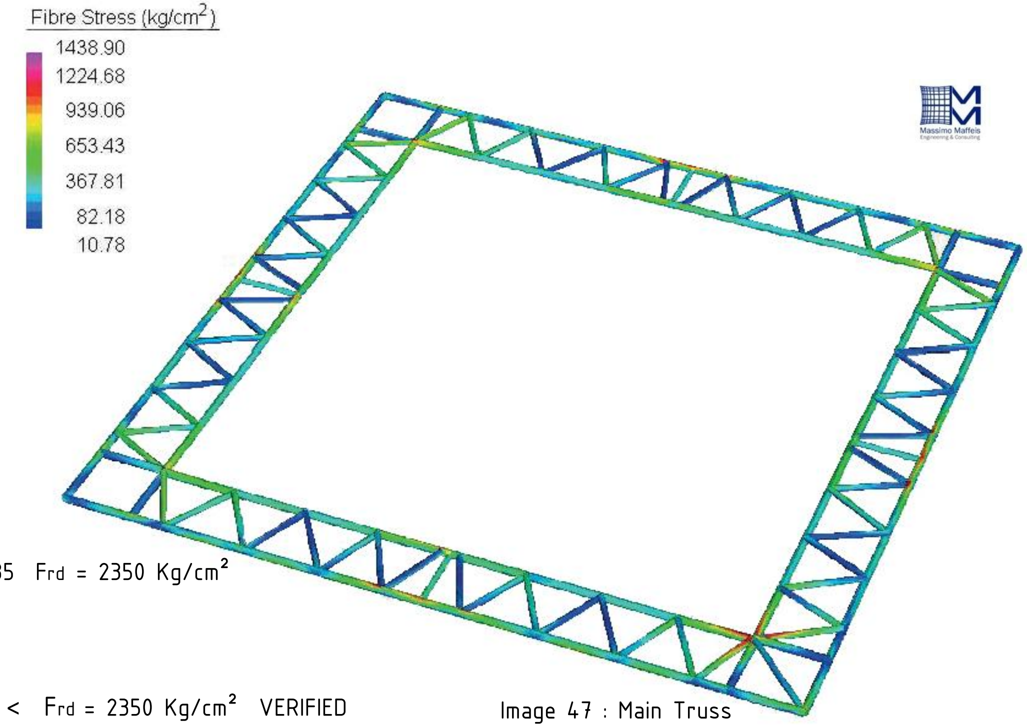


Image 46 : Main Truss

From the pictures below it is possible to see the maximum steel stress of the mast :



In accordance to EC3 the tension design is calculated :

S235 F_{rd} = 2350 Kg/cm^2

Safety Factor for steel design = 1.5

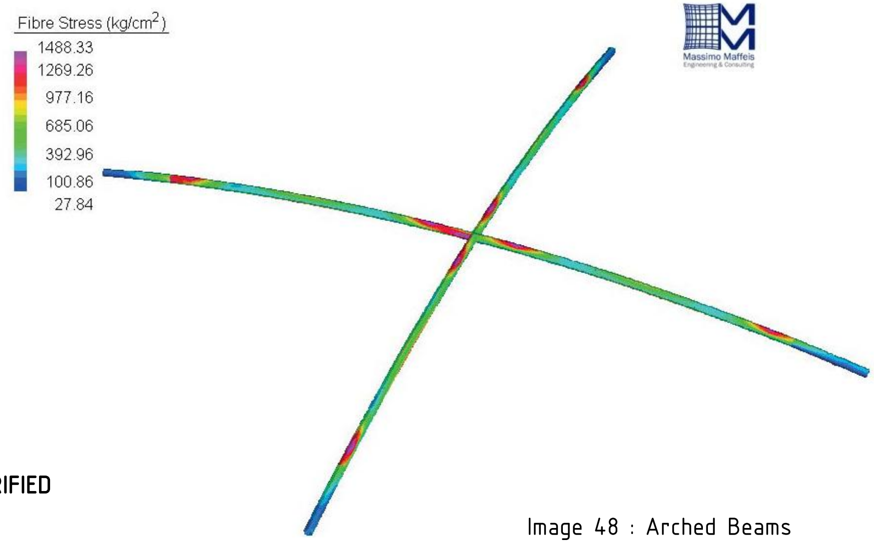
So Steel elements is :

F_{sd} = 1438.9x1.5= 2158.35 kg/cm^2 < F_{rd} = 2350 Kg/cm^2 VERIFIED

Image 47 : Main Truss

2-5-2 Arches

The Arcs have a cross-section of Ø219 mm with thickness 7 mm, on image below it is possible to see the maximum steel stress.



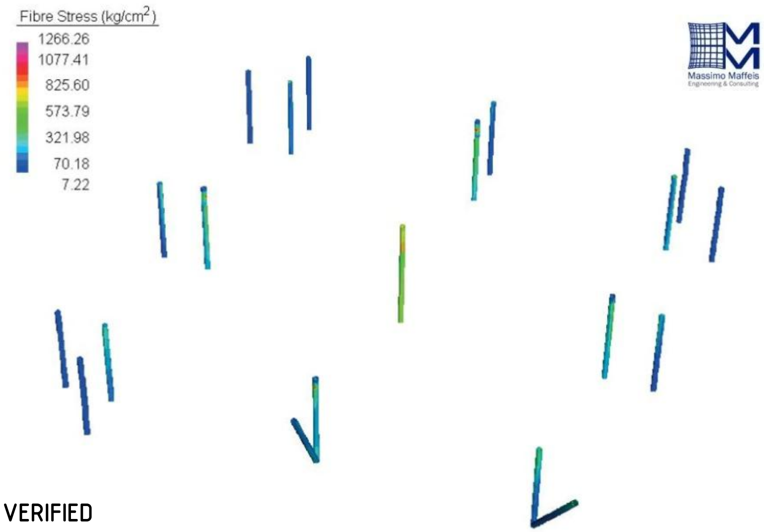
So Steel elements is :

$F_{sd} =$ 1488x1.5= 2232.5 kg/cm^2 < F_{rd} = 2350 Kg/cm^2 **VERIFIED**

Image 48 : Arched Beams

2-5-3 Columns

The border columns have a cross-section of Ø219 mm with thickness 3 mm, on image below it is possible to see the maximum steel stress



So Steel elements is :

$F_{sd} =$ 1266.26x1.5= 1899.39 kg/cm^2 < F_{rd} = 2350 Kg/cm^2 **VERIFIED**

Image 49 : Columns

2-5-4 Fly-mast

The Fly Mast elements have a cross-section of Ø168 mm with thickness 4 mm on image below it is possible to see the maximum steel stress

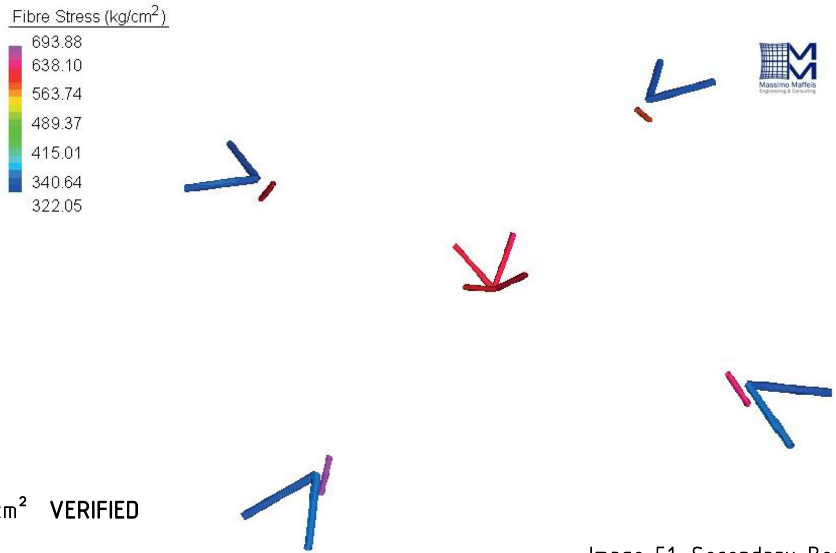
So Steel elements is :

F_{sd} = 547.14x1.5= 820.71 kg/cm² < F_{rd} = 2350 Kg/cm² **VERIFIED**

Image 50 : Fly-Masts

2-5-5 Pipes of reinforce

From the pictures below it is possible to see the maximum steel stress



So Steel elements is :

F_{sd} = 693.88x1.5= 1040.82 kg/cm² < F_{rd} = 2350 Kg/cm² **VERIFIED**

Image 51: Secondary Beams

2-6 Components Arrangement

2-6-1 Base Plates

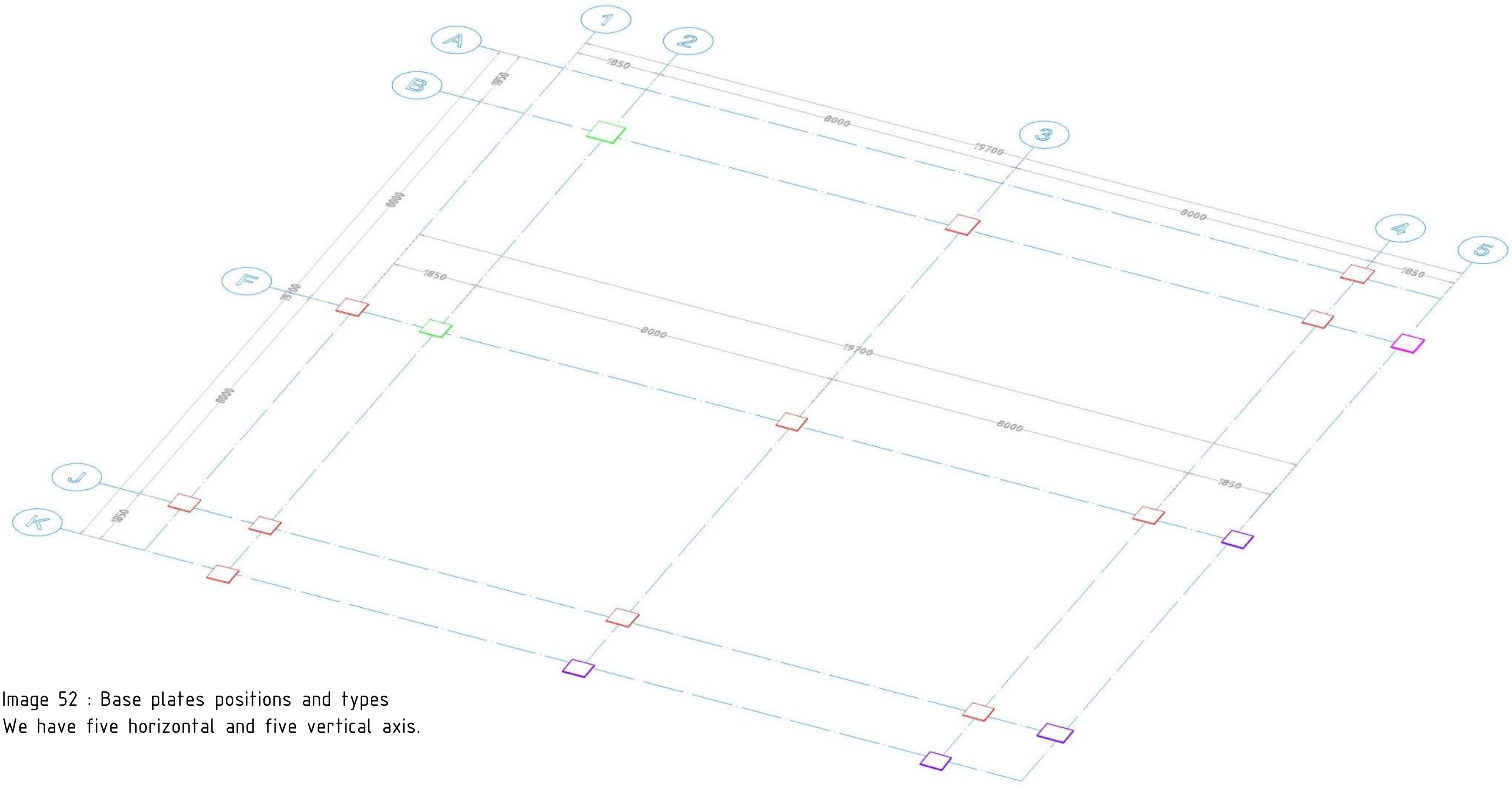


Image 52 : Base plates positions and types
We have five horizontal and five vertical axis.

2-6 Components Arrangement

2-6-2 Columns

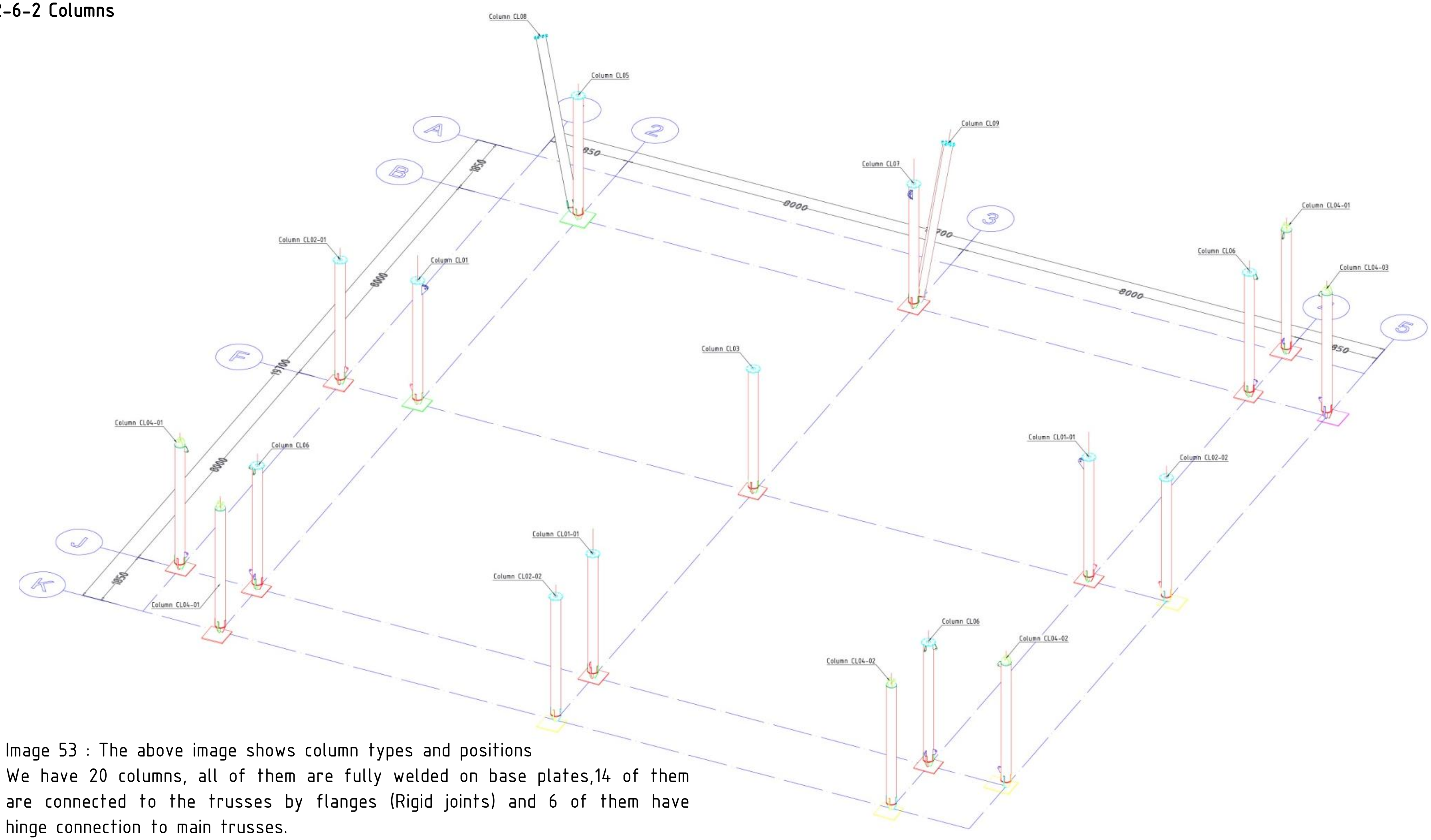


Image 53 : The above image shows column types and positions

We have 20 columns, all of them are fully welded on base plates,14 of them are connected to the trusses by flanges (Rigid joints) and 6 of them have hinge connection to main trusses.

2-6 Components Arrangement

2-6-3 Bracing

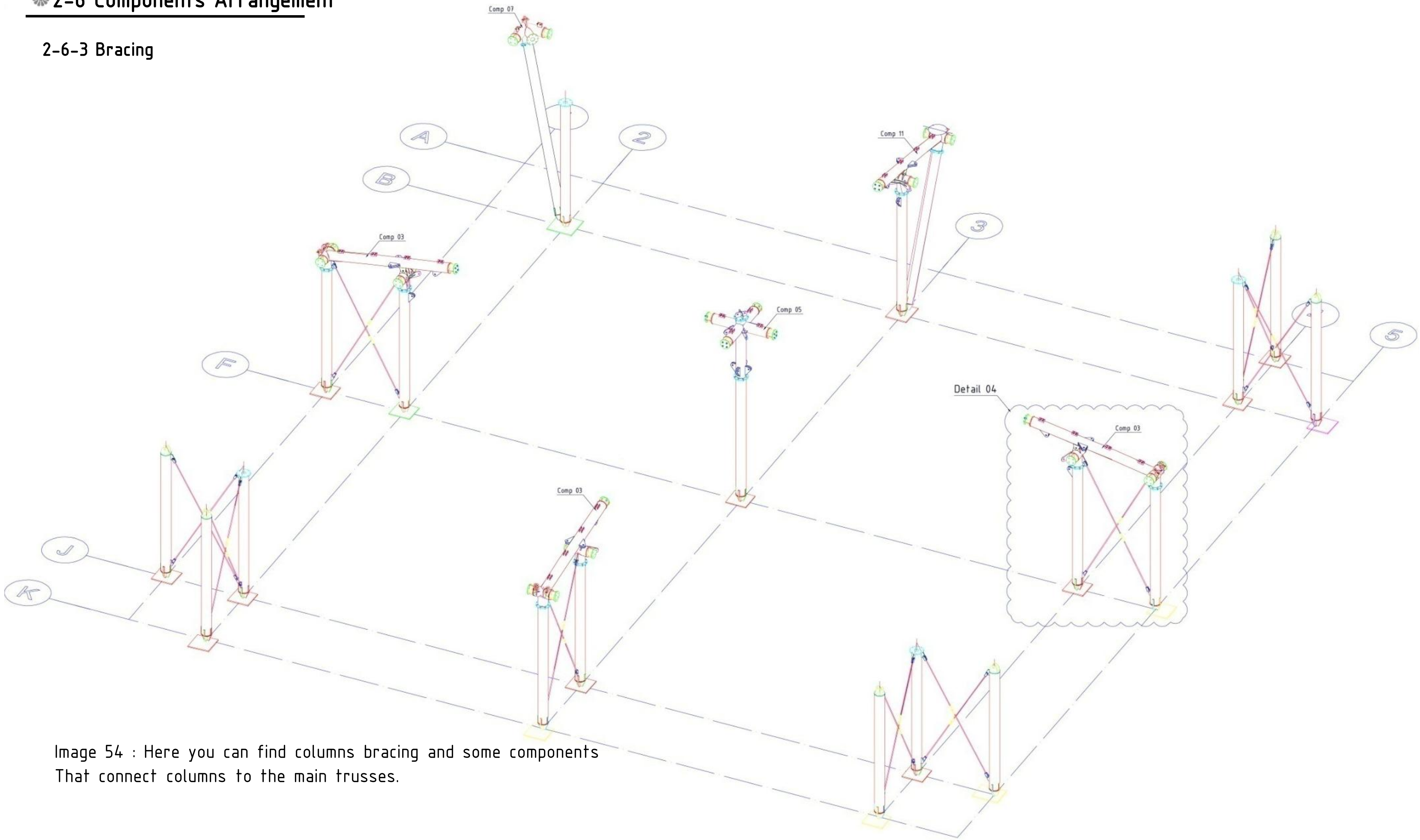


Image 54 : Here you can find columns bracing and some components
That connect columns to the main trusses.

2-6 Components Arrangement

2-6-4: Arches

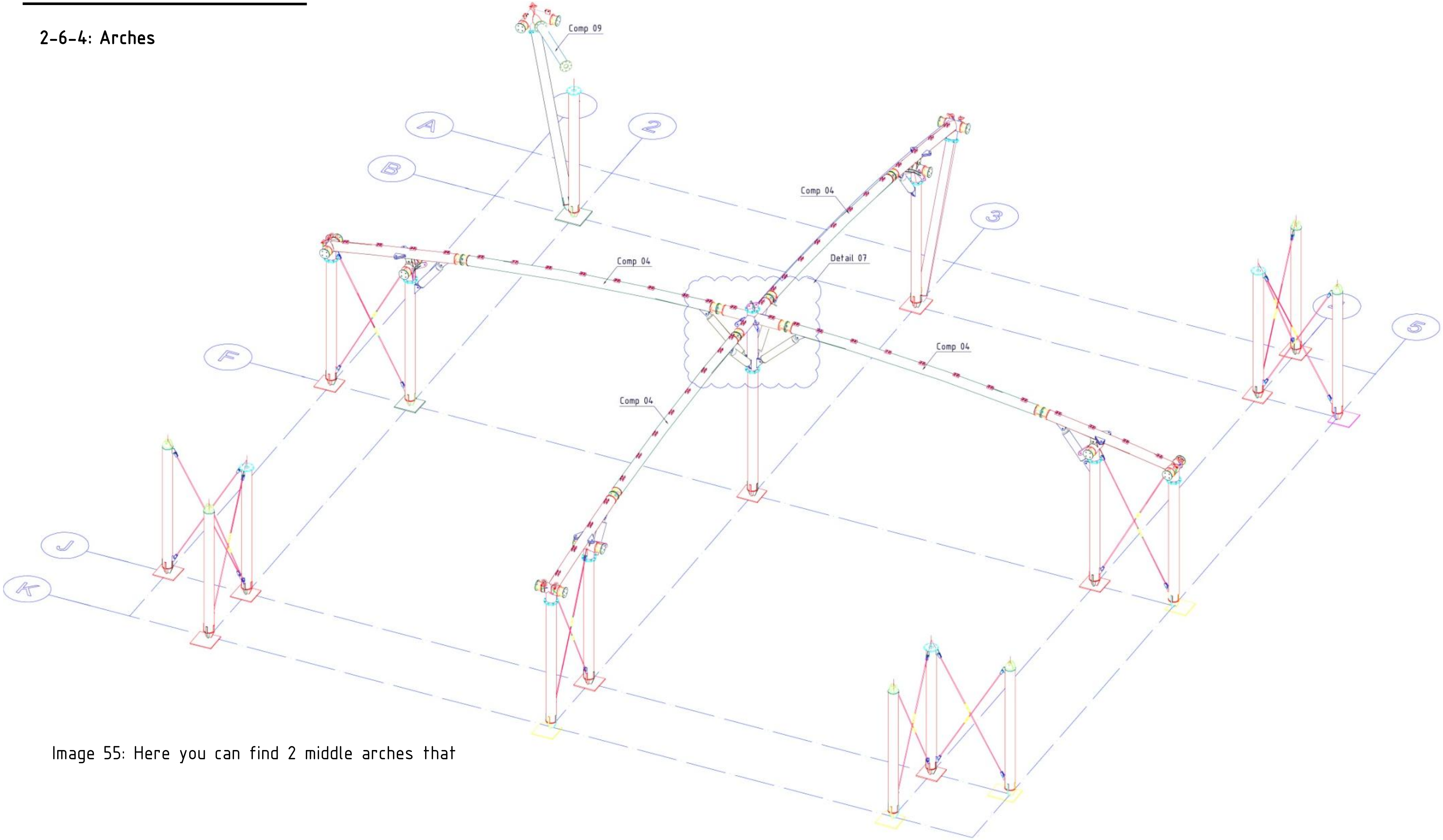


Image 55: Here you can find 2 middle arches that

2-6 Components Arrangement

2-6-5 Trusses

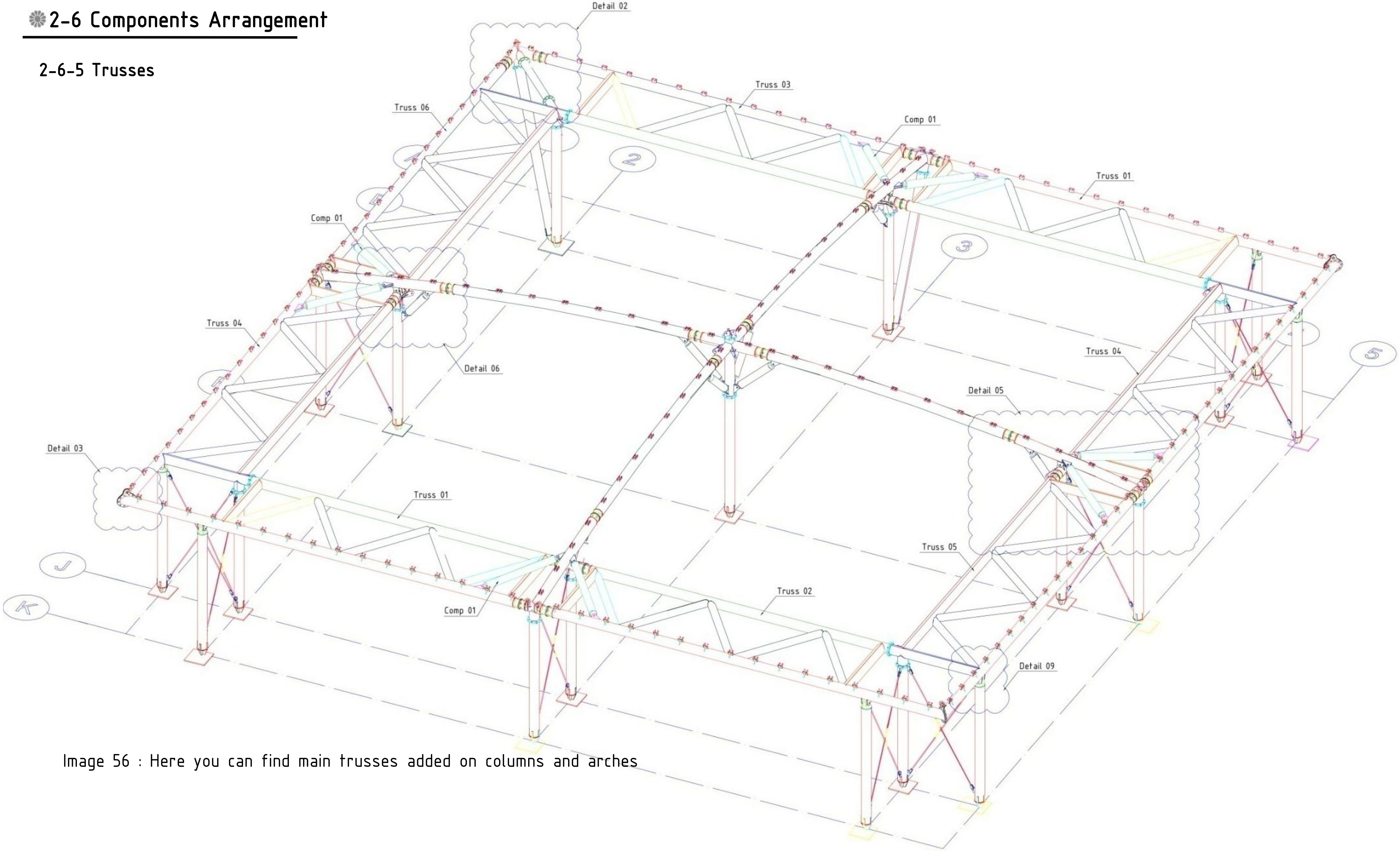


Image 56 : Here you can find main trusses added on columns and arches

2-6 Components Arrangement

2-6-6 Fly-masts

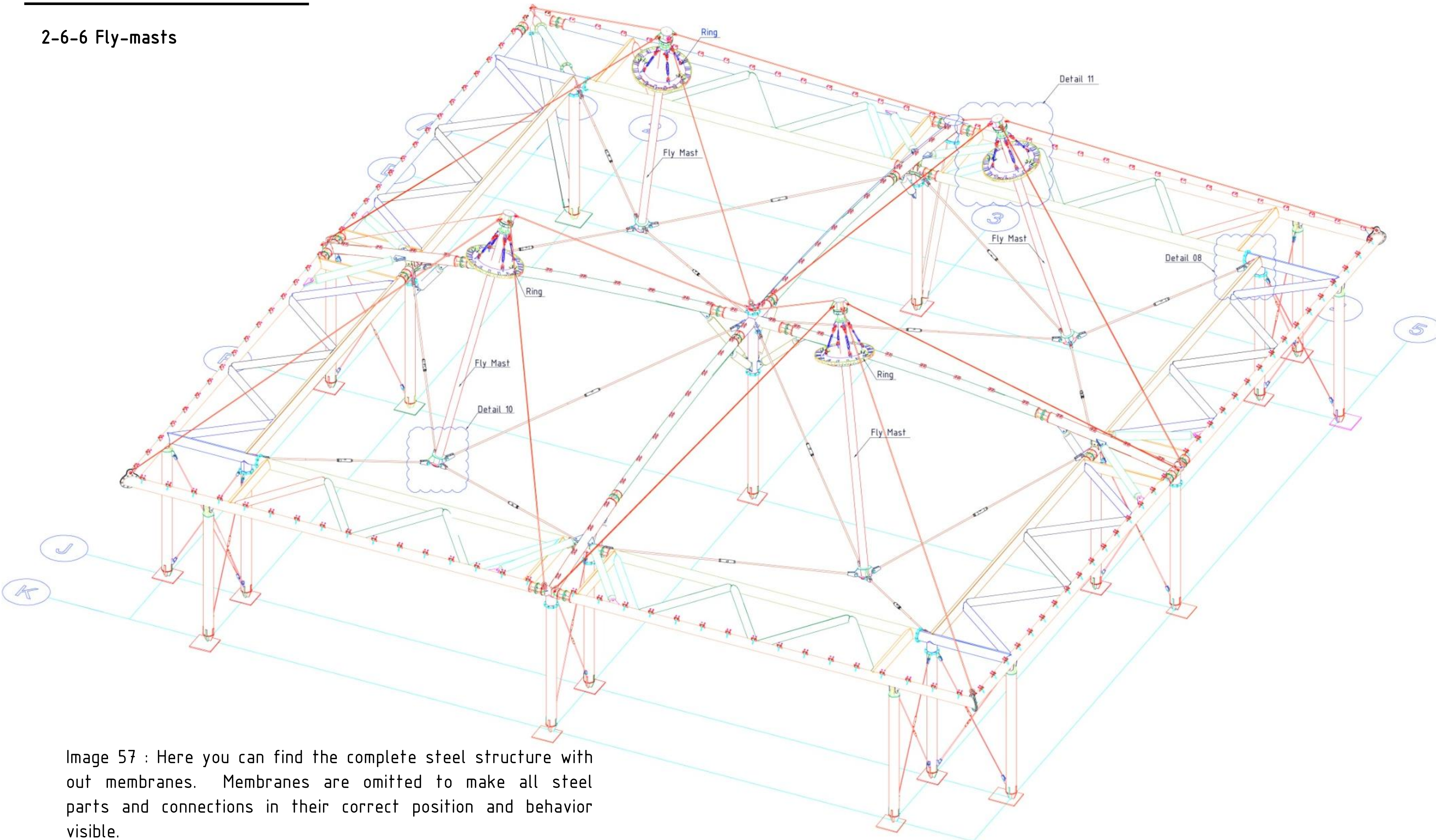


Image 57 : Here you can find the complete steel structure with out membranes. Membranes are omitted to make all steel parts and connections in their correct position and behavior visible.

❋2-6 Components Arrangement

2-6-7 Membrane

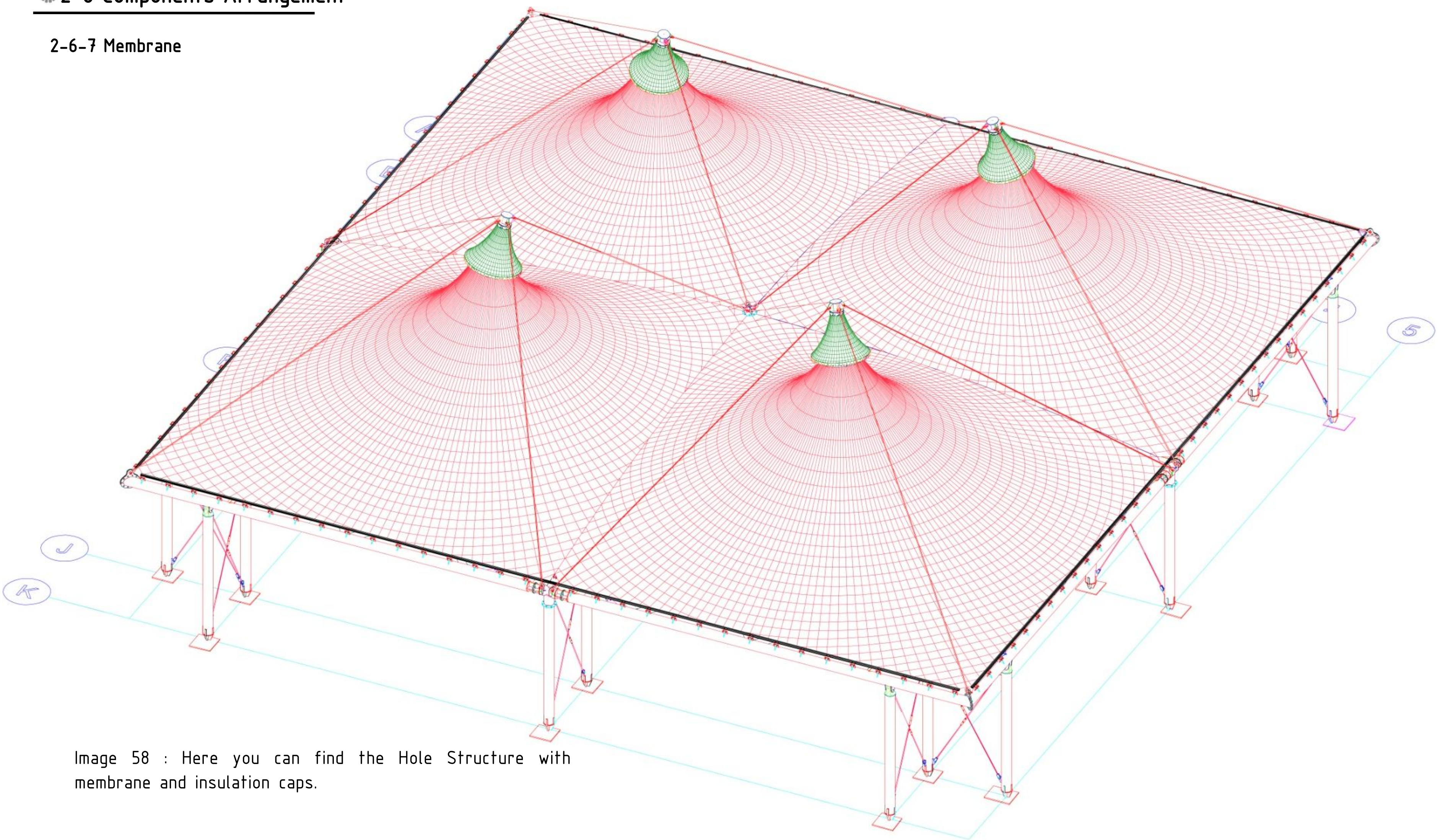


Image 58 : Here you can find the Hole Structure with membrane and insulation caps.

2-7 Structure Details

Detail 01

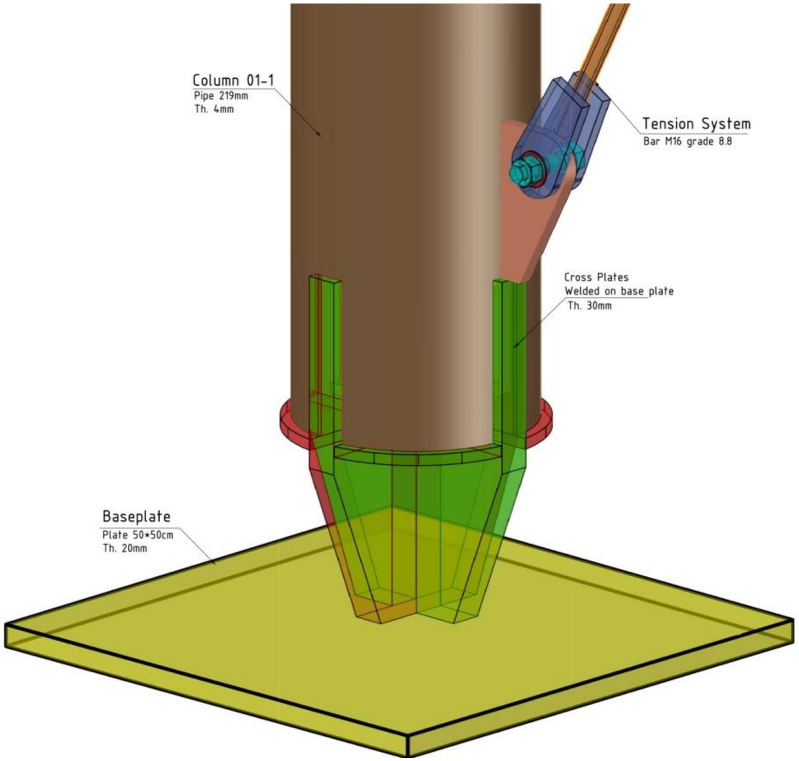


Image 59 : there is a cross plate for columns connection to the base plates ,that is welded inside the pipe grooves and it must be welded on base plates in bottom.

Detail 02

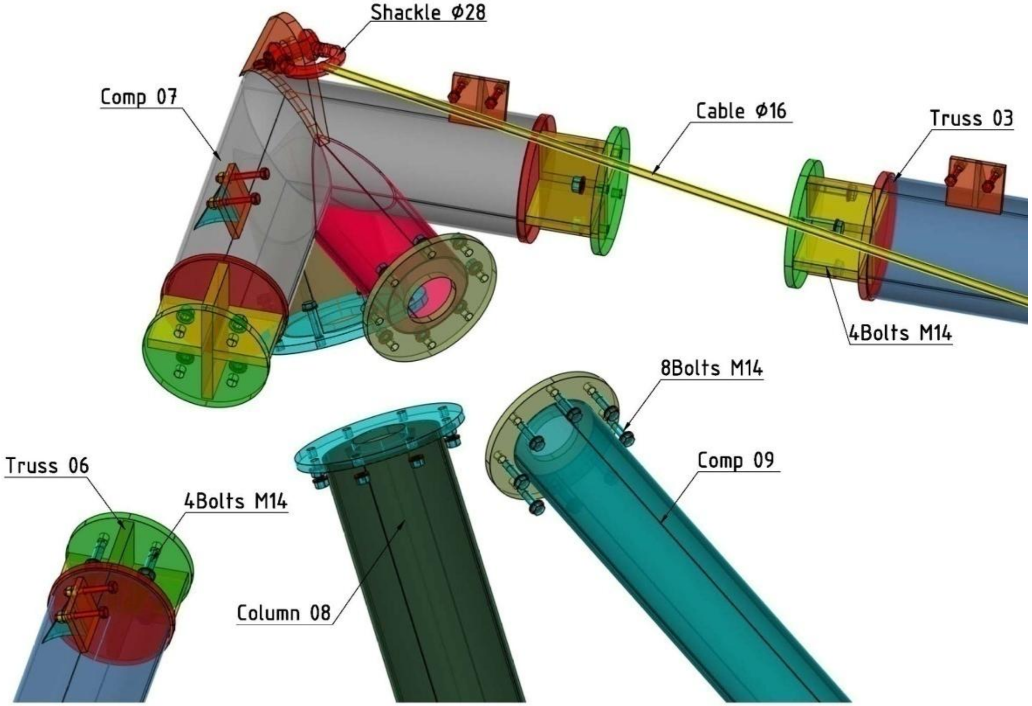


Image 60 : The above image shows a corner detail in north west part of structure, Comp 07 connects 4 other components (comp 08,09 and truss 03,04) to each other with flanges.

2-7 Structure Details

Detail 03

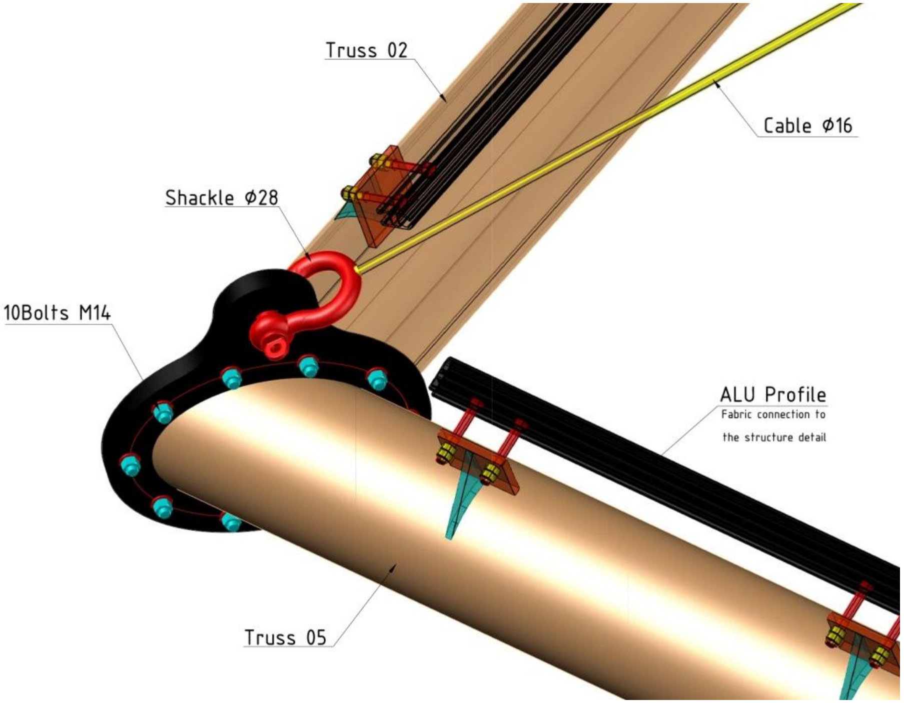


Image 61 : The above image shows the detail in 3 other corners of structure, Truss 02 and 05 connect to each other with flange.

Detail 04

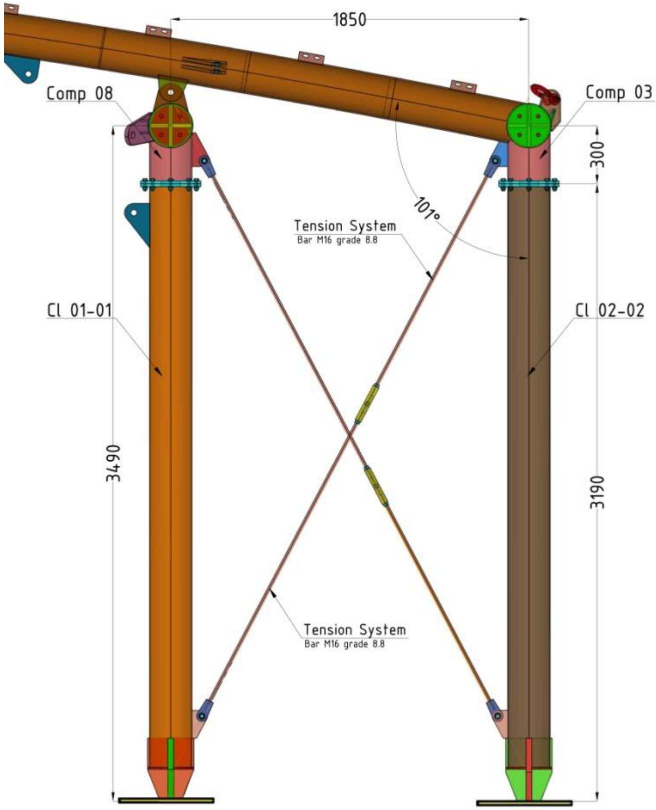


Image 62 : The above image shows the bracing detail for connecting columns to each other in bottom and top part and help them work as a single truss to prevent columns from torsion.

2-7 Structure Details

Detail 05

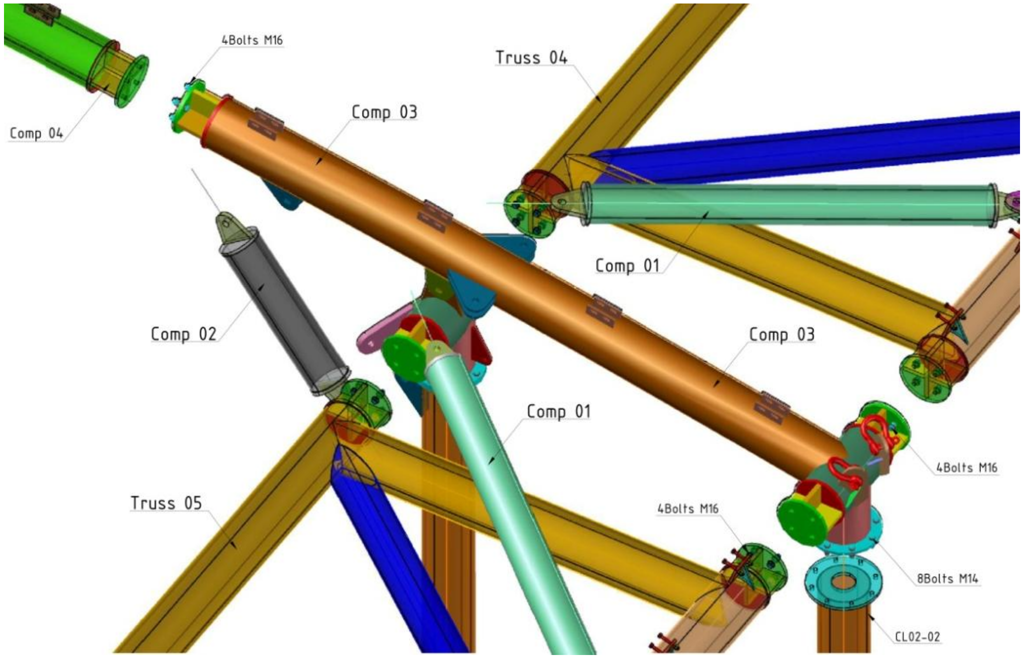


Image 63 : The above image shows how the component 03 in middle of each edge of structure connects to other components with flanges and hinge connections.

Detail 06

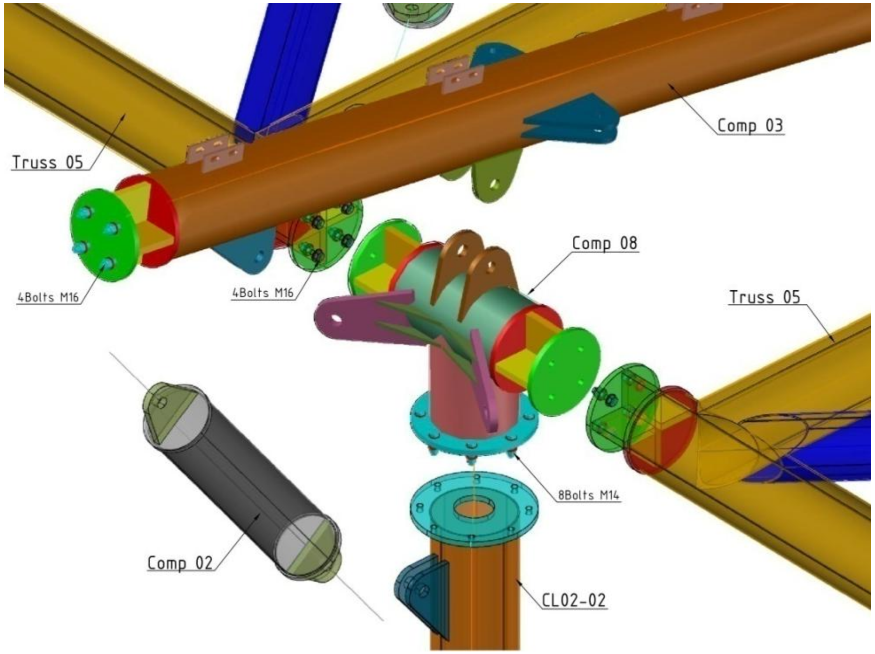


Image 64 : The above image shows comp 08 connection to column ,trusses and other components in middle parts of structure edges

2-7 Structure Details

Detail 07

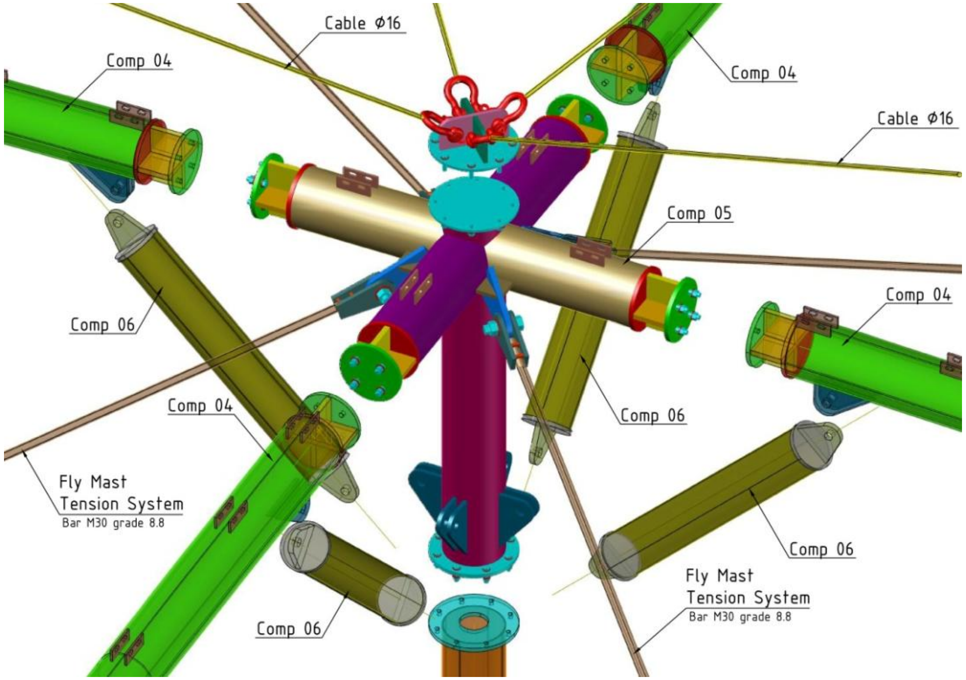


Image 65 : The above image shows the column detail and connection to the arches in center part of the structure, and also shows how fly mast tension systems and safety cables connect to the center column

Detail 08

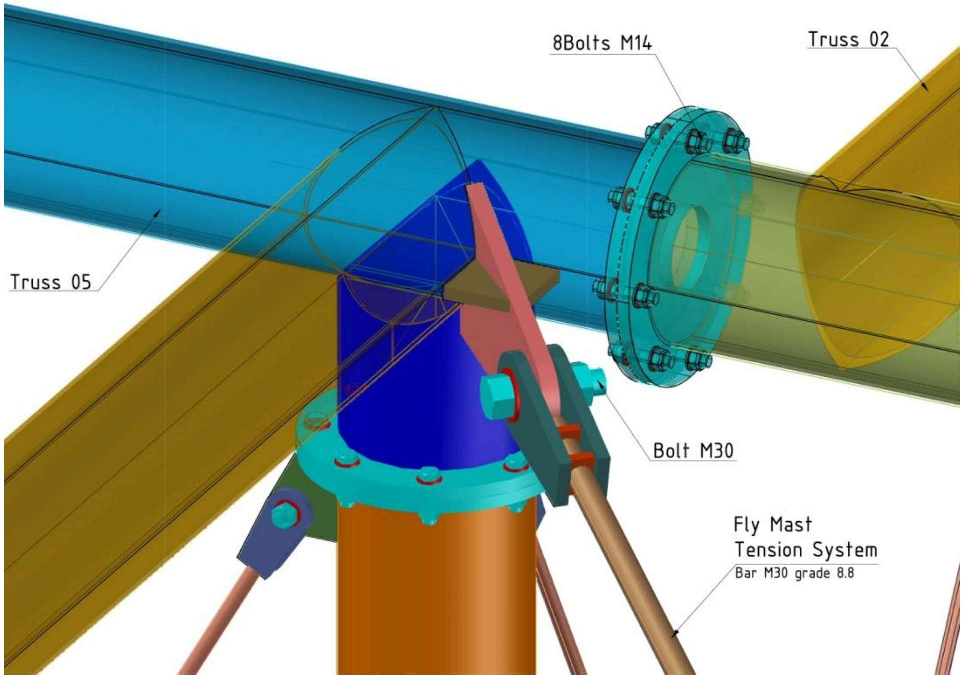


Image 66 : The above image shows Truss flange connection to column

2-7 Structure Details

Detail 09

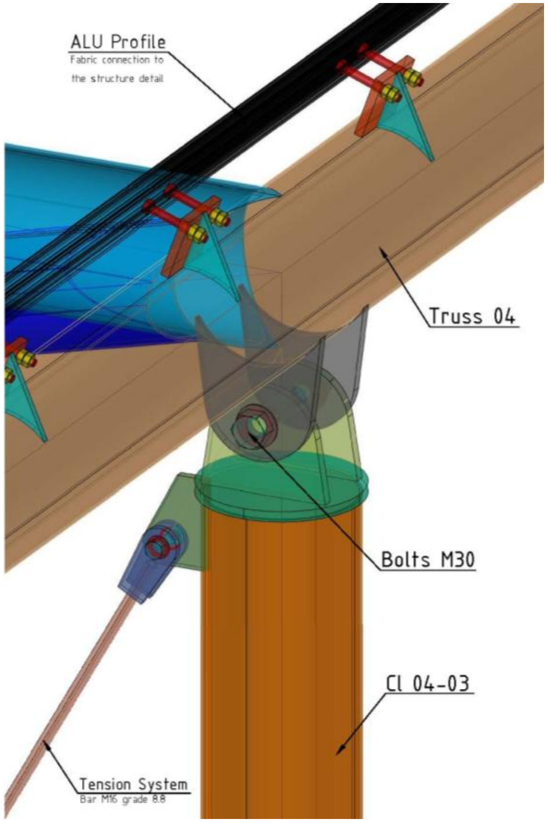


Image 67 : The above image shows the corner columns .hinge connection to the main trusses

Detail 10

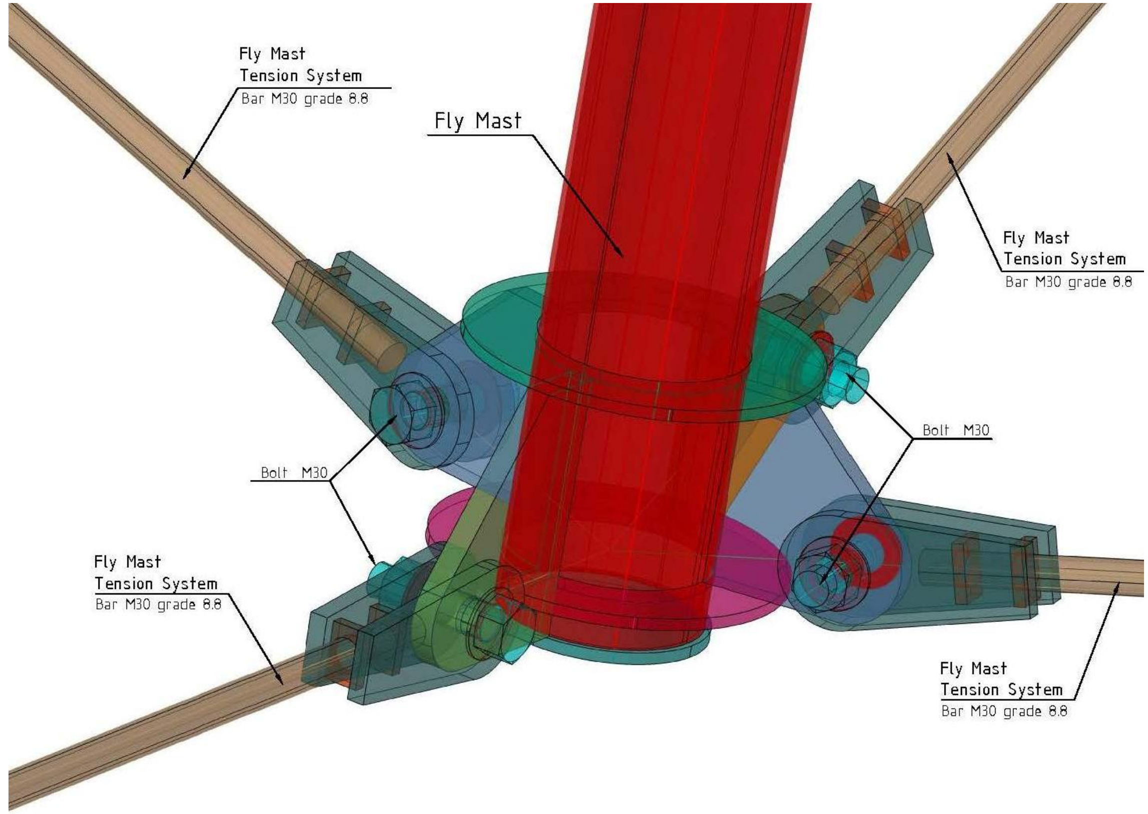
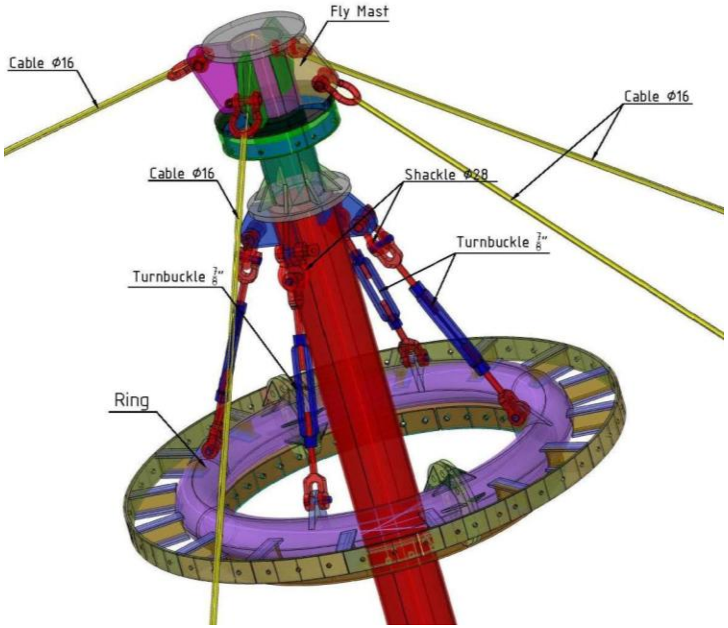
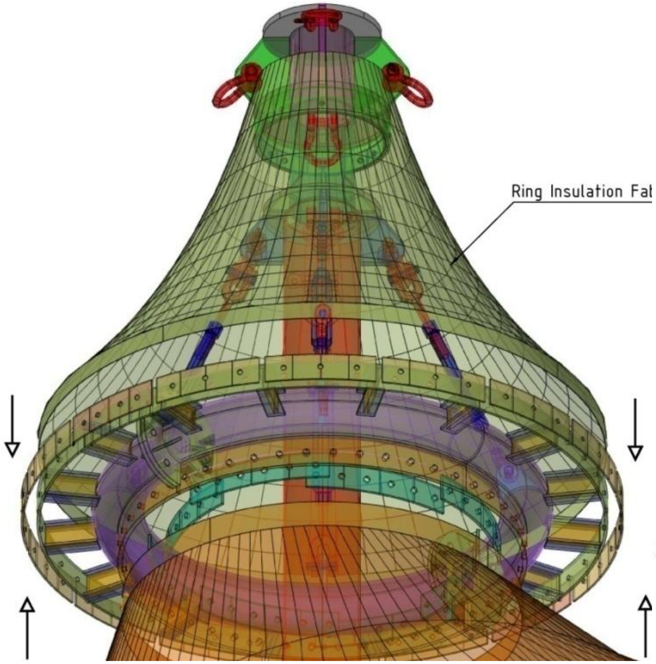


Image 68 : The above image shows the bottom detail of fly masts with tension systems.

2-7 Structure Details

Detail 11





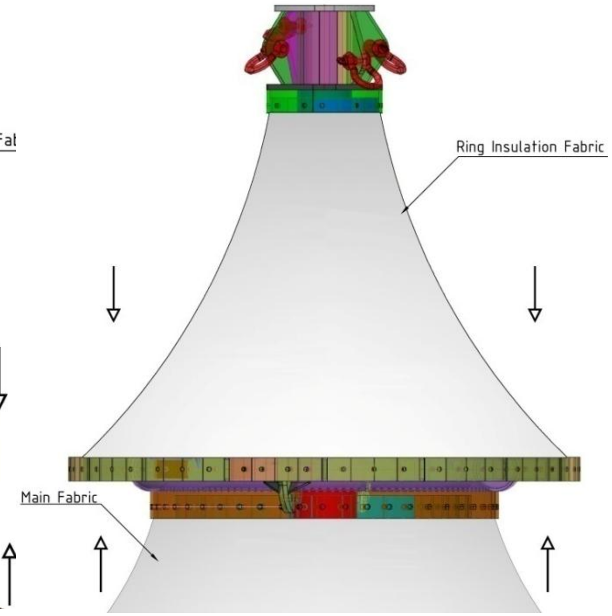
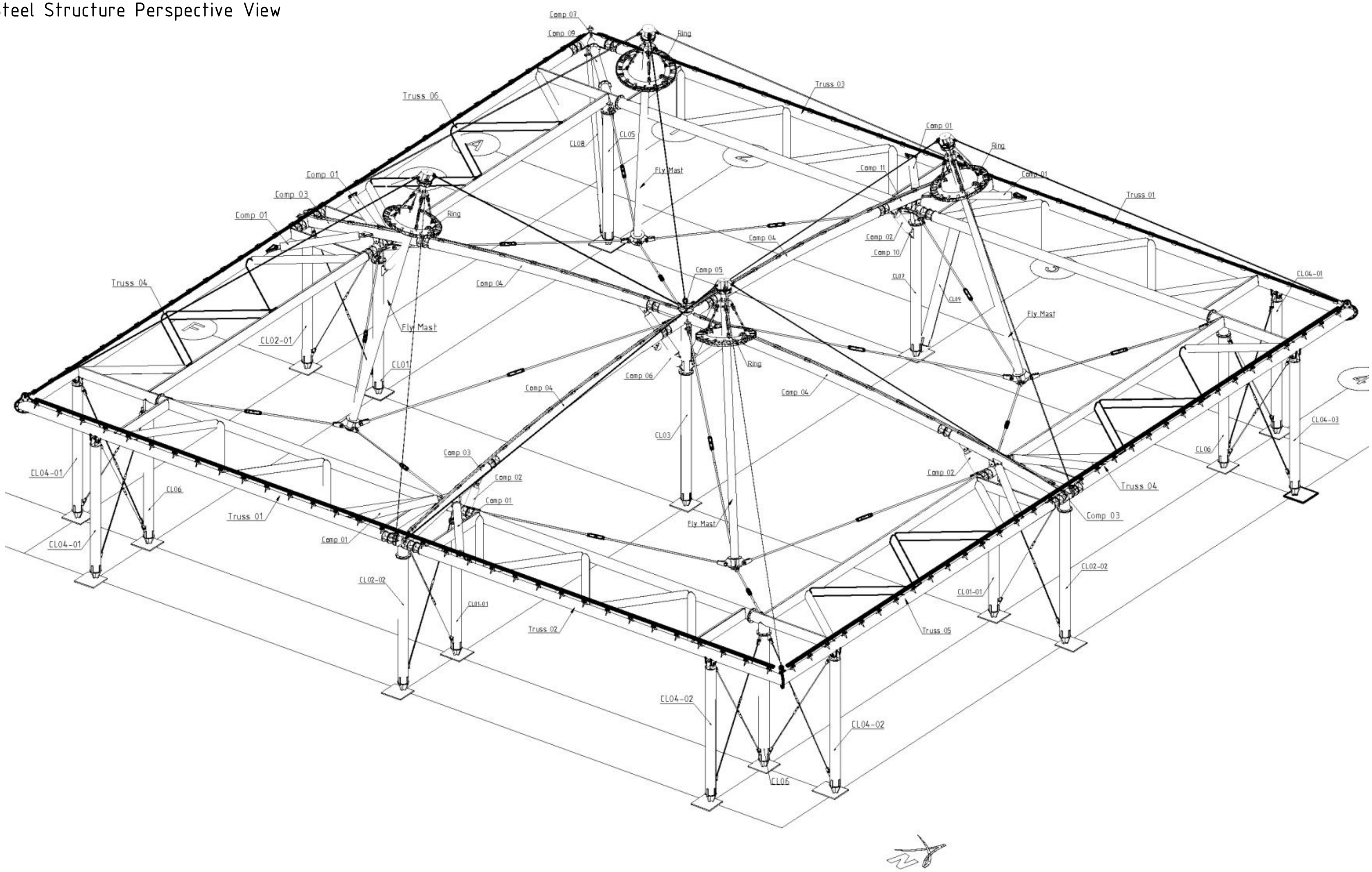


Image 69 : The above images show the top of fly masts and ring details ,also it shows the ring insulation fabric. In our design process we considered the air circulation from the top part of each highpoint fabric .it helped us to provide natural ventilation and to evacuate bad smell from inside the restaurant ,we have an opening between main fabric and insulation fabric at their connections to the rings,this opening is located under the insulation fabric so it won't let rain splash inside.

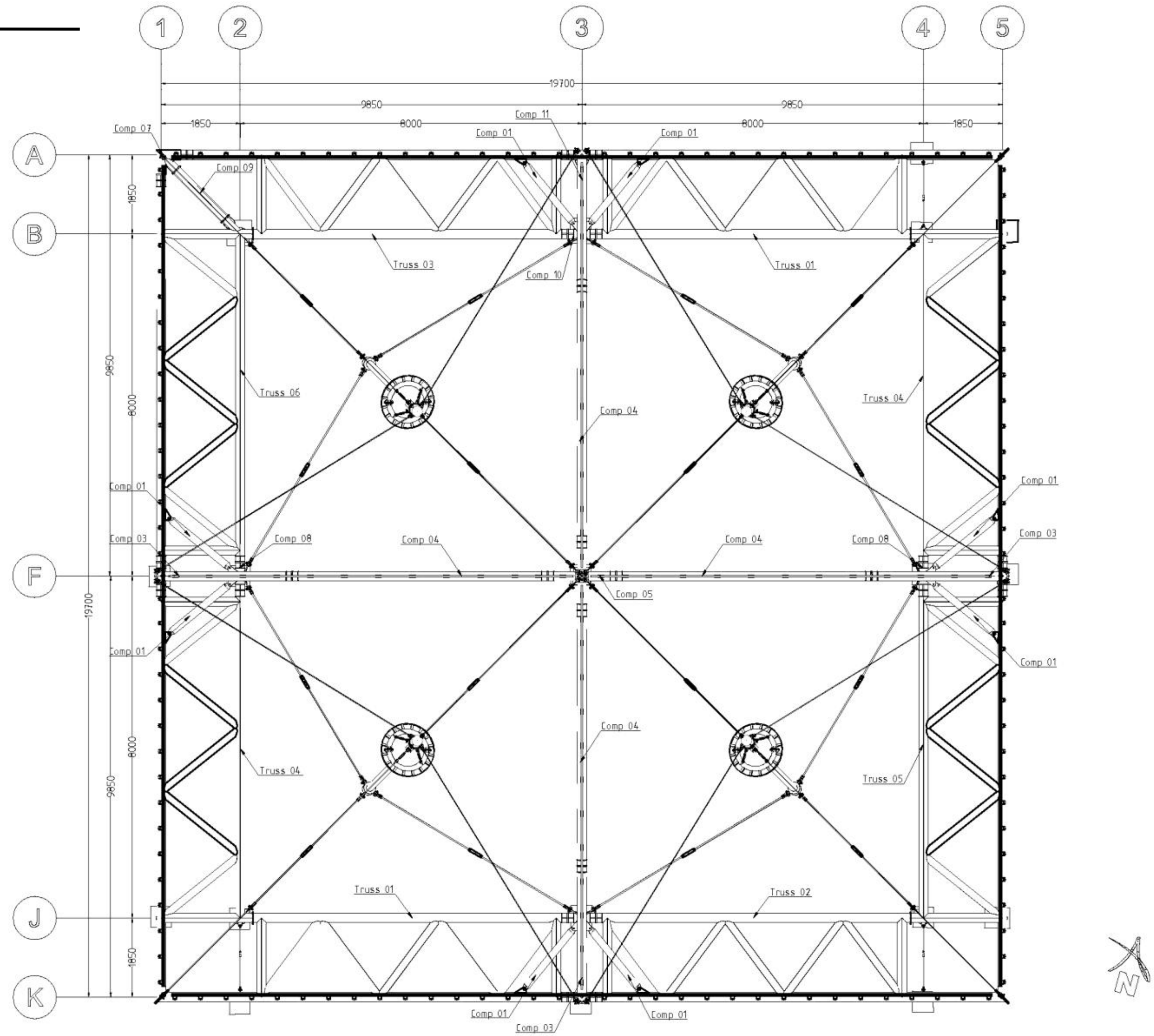
2-8 Shop Drawing

Steel Structure Perspective View



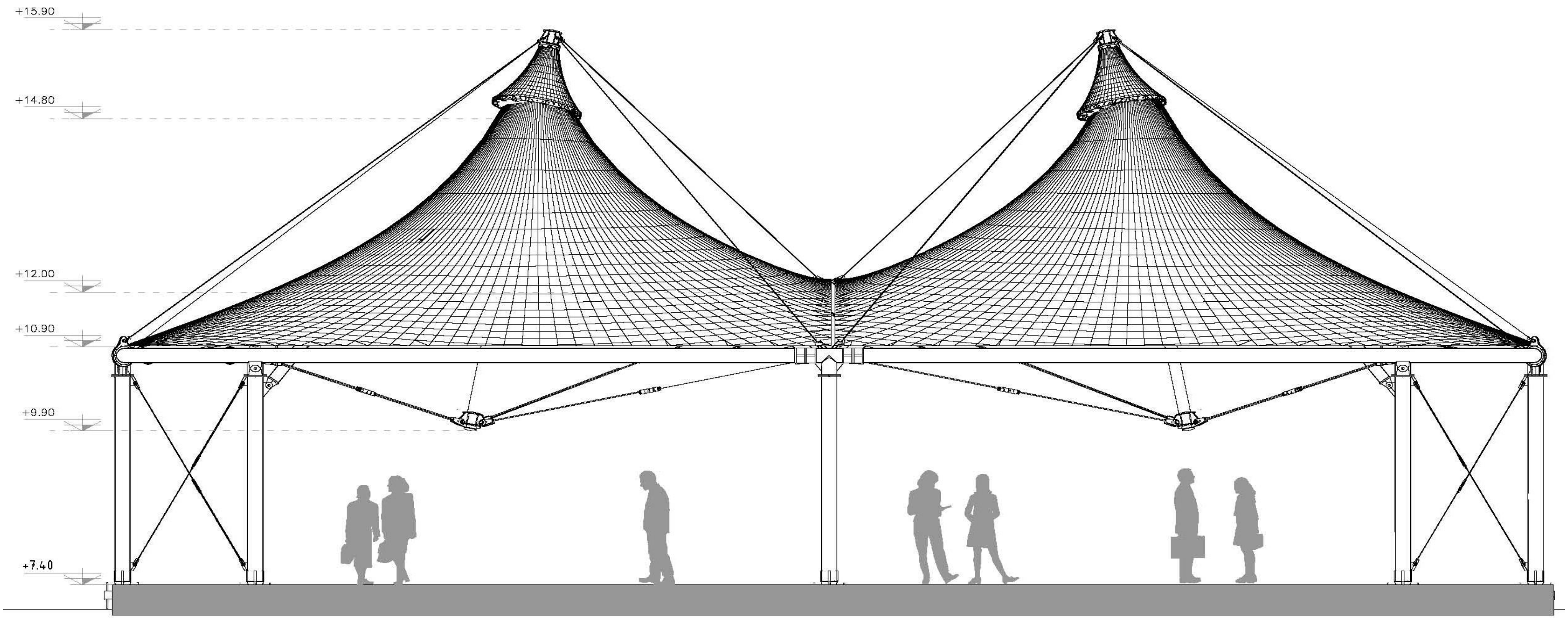
2-8 Shop Drawing

Plan View



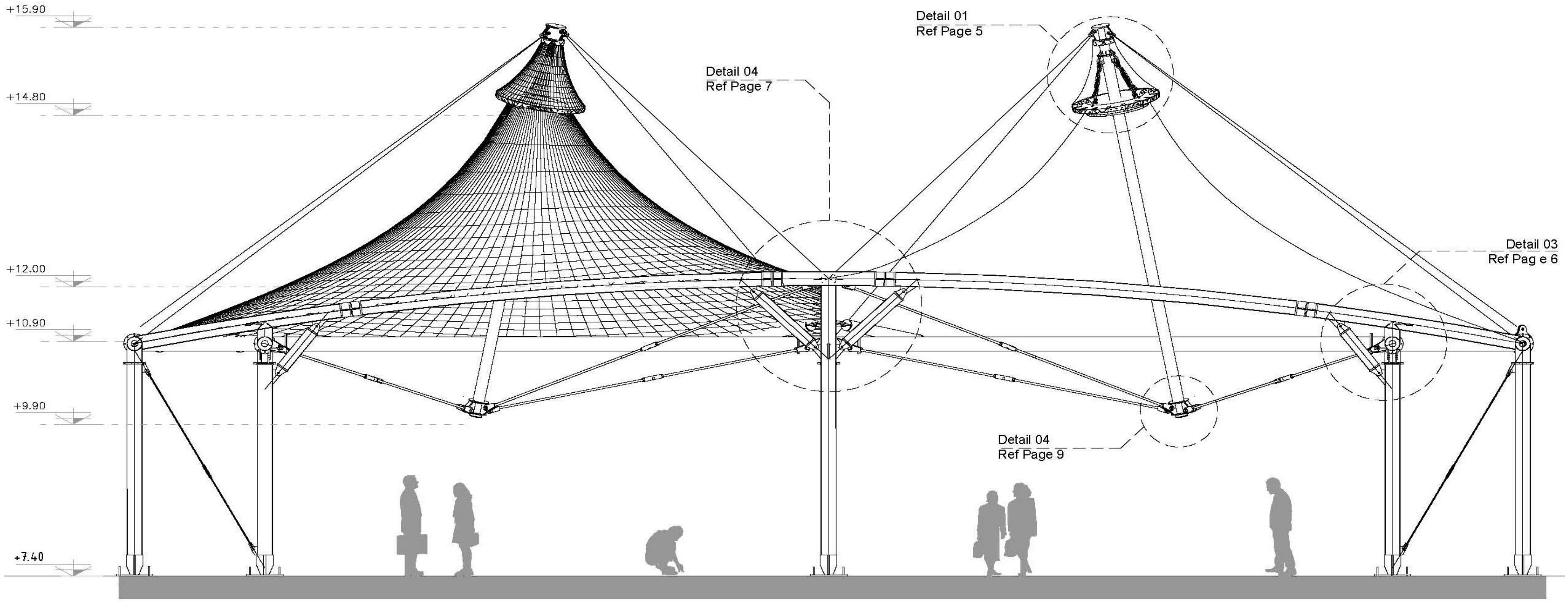
2-8 Shop Drawing

Front View



2-8 Shop Drawing

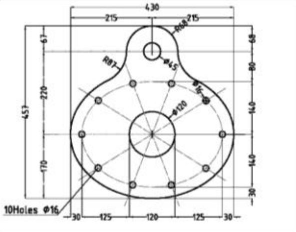
Section



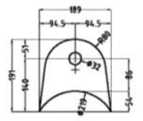
2-8 Shop Drawing

Plates :

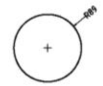
PL006	TH=15
N=6	CNC



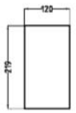
PL007	TH=15
N=12	CNC



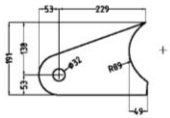
PL008	TH=20
N=36	CNC



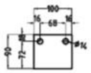
PL009	TH=20
N=52	



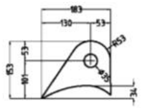
PL010	TH=20
N=4	CNC



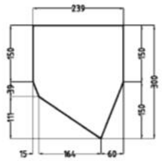
PL056	TH=12
N=134	



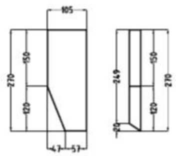
PL057	TH=15
N=4	CNC



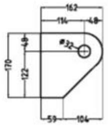
PL058	TH=30
N=1	CNC



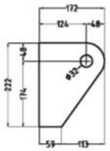
PL059	TH=30
N=2	CNC



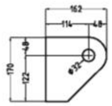
PL060	TH=20
N=8	CNC



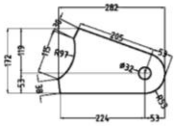
PL061	TH=20
N=4	CNC



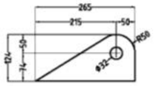
PL062	TH=20
N=4	CNC



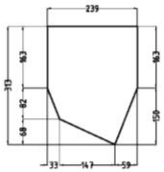
PL063	TH=20
N=4	CNC



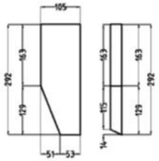
PL064	TH=15
N=8	CNC



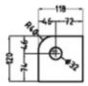
PL065	TH=30
N=1	CNC



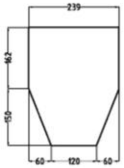
PL066	TH=30
N=2	CNC



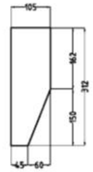
PL067	TH=15
N=2	CNC



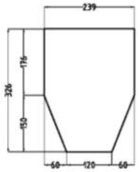
PL068	TH=30
N=11	CNC



PL069	TH=30
N=22	CNC

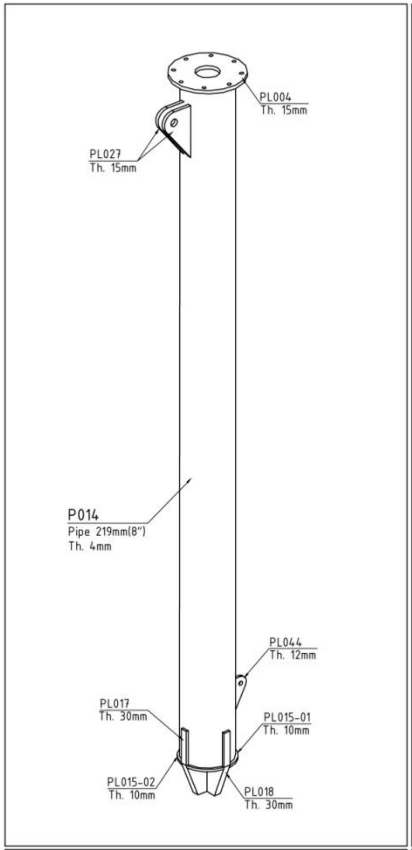


PL070	TH=30
N=4	CNC

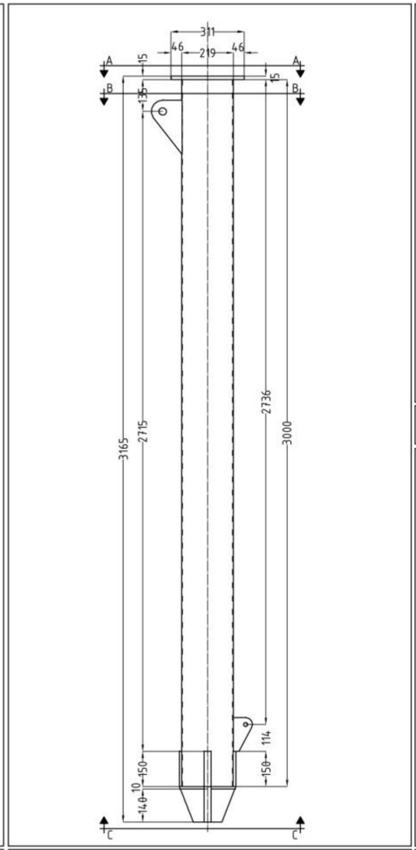


2-8 Shop Drawing

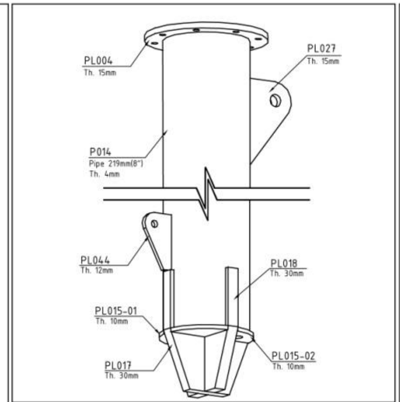
Column



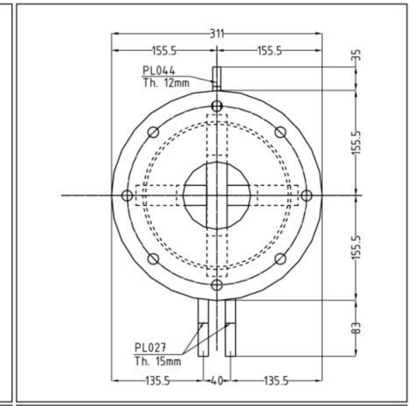
3D View



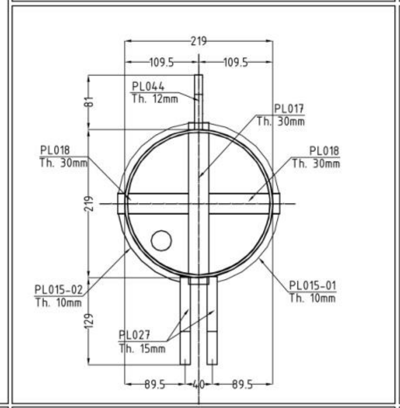
Side View



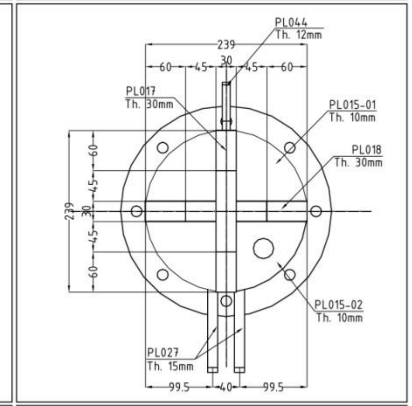
3D View



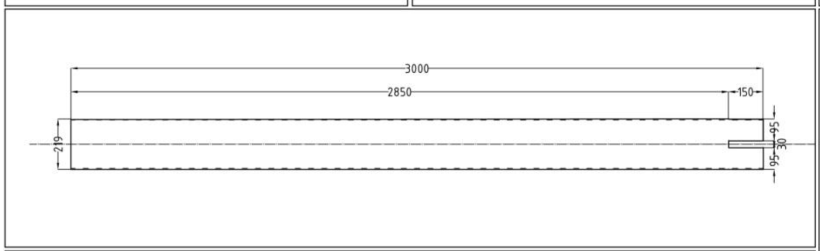
View A_A



Section B_B



View C_C



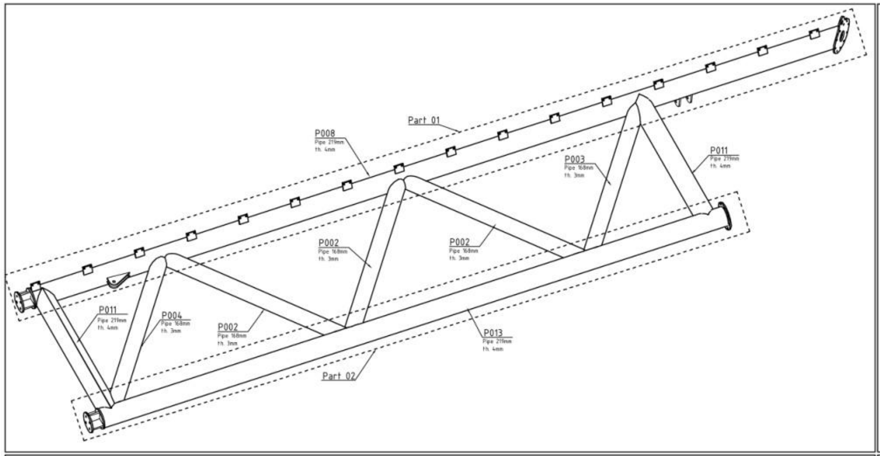
P014 (Pipe 219.1mm Th. 4mm)

Quantity for One Assembling

N°	OBJECT	QTY	THICKNESS	MATERIAL	NOTE
P014	PIPE ø 219.1 mm	1	4 mm	STEEL S235	/
PL004	Plate PL004	1	15 mm	STEEL S235	/
PL015-01	Plate PL015-01	3	10 mm	STEEL S235	/
PL015-02	Plate PL015-02	1	10 mm	STEEL S235	/
PL017	Plate PL017	1	30 mm	STEEL S235	/
PL018	Plate PL018	2	30 mm	STEEL S235	/
PL027	Plate PL027	2	15 mm	STEEL S235	/
PL044	Plate PL044	1	12 mm	STEEL S235	/

2-8 Shop Drawing

Truss

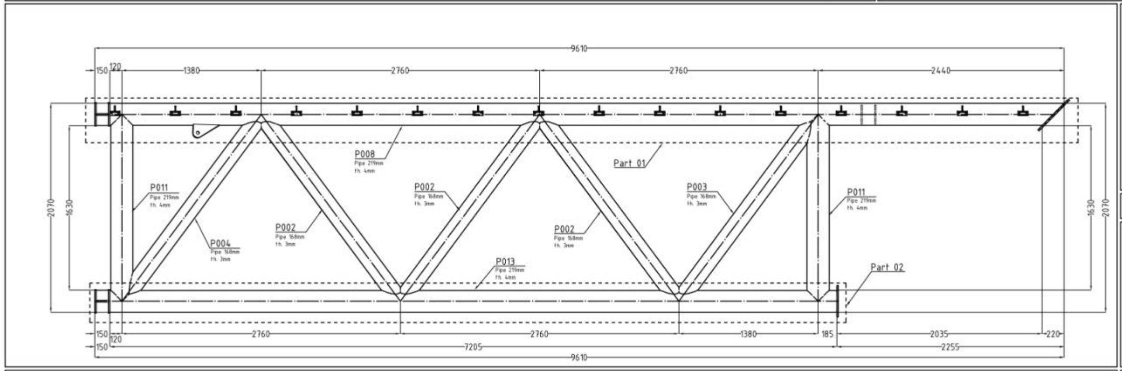


3D View Qty= 2

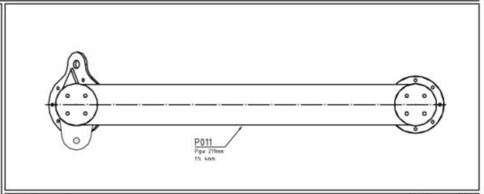
Table

Quantity for 2 Trusses 01

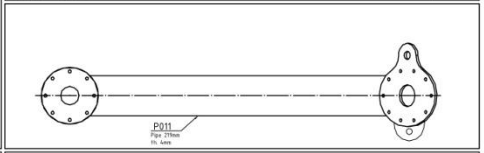
N°	OBJECT	QTY	THICKNESS	MATERIAL	NOTE
P002	PIPE ϕ 168.3 mm	6	3 mm	STEEL S235	/
P003	PIPE ϕ 168.3 mm	2	3 mm	STEEL S235	/
P004	PIPE ϕ 168.3 mm	2	3 mm	STEEL S235	/
P008	PIPE ϕ 219.1 mm	2	4 mm	STEEL S235	/
P011	PIPE ϕ 219.1 mm	4	4 mm	STEEL S235	/
P013	PIPE ϕ 219.1 mm	2	4 mm	STEEL S235	/
PL001	Plate PL001	4	15 mm	STEEL S235	/
PL002	Plate PL002	8	20 mm	STEEL S235	/
PL003	Plate PL003	4	15 mm	STEEL S235	/
PL004	Plate PL004	2	15 mm	STEEL S235	/
PL005	Plate PL005	2	15 mm	STEEL S235	/
PL006	Plate PL006	2	15 mm	STEEL S235	/
PL007	Plate PL007	4	15 mm	STEEL S235	/
PL009	Plate PL009	4	20 mm	STEEL S235	/
PL030	Plate PL030	32	10 mm	STEEL S235	/
PL056	Plate PL056	32	12 mm	STEEL S235	/
PL064	Plate PL064	2	15 mm	STEEL S235	/



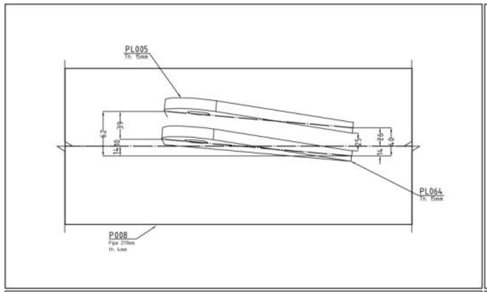
Plan View Qty= 2



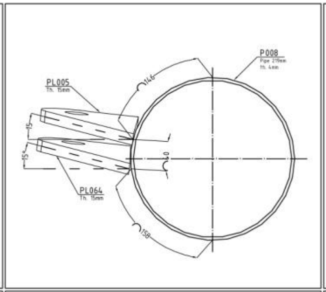
Left View Qty= 2



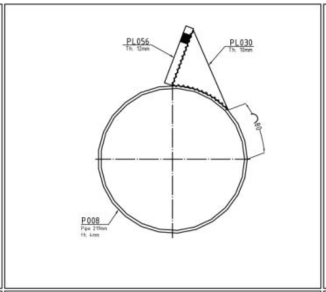
Right View Qty= 2



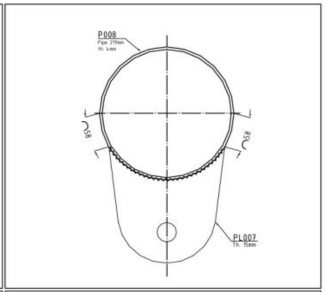
Detail 03



Section A.A



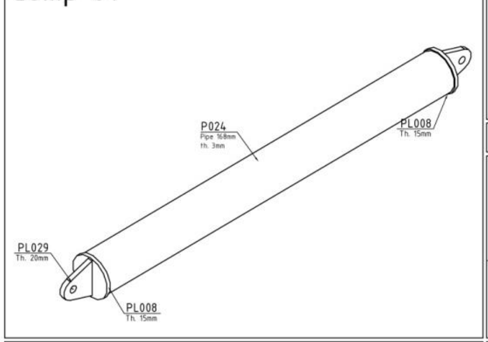
Section B.B



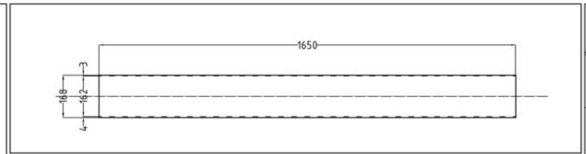
Section C.C

2-8 Shop Drawing

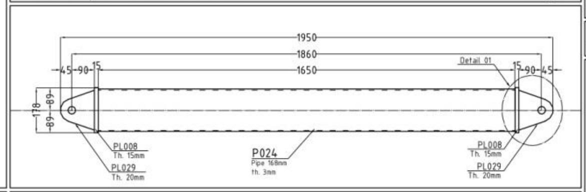
Comp 01



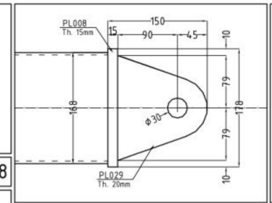
3D View Qty=8



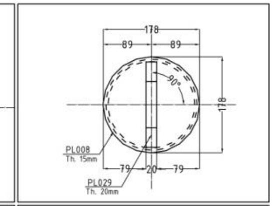
P024 (Pipe 168mm th. 3mm) Qty=8



Side View



Detail 01

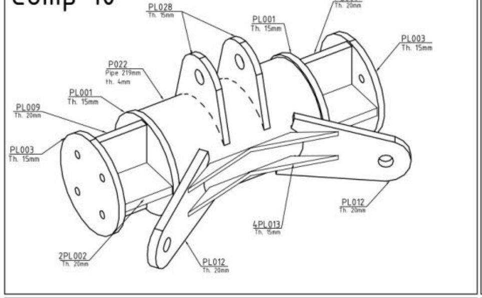


Bottom View

Quantity for 8 Components 01

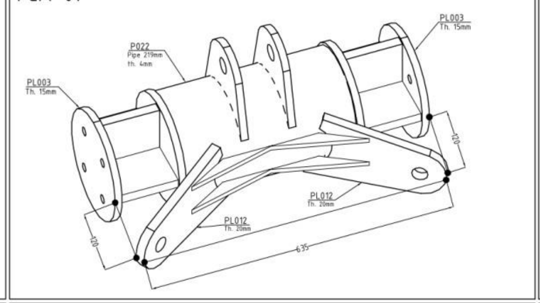
N°	OBJECT	QTY	THICKNESS	MATERIAL	NOTE
P024	PIPE ϕ 168.3 mm	8	3 mm	STEEL S235	/
PL008	Plate PL008	16	15 mm	STEEL S235	/
PL029	Plate PL029	16	20 mm	STEEL S235	/

Comp 10



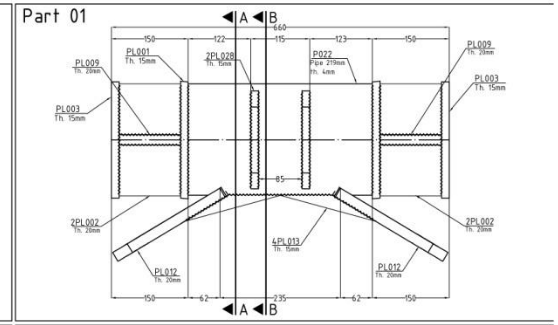
3D View Qty=1

Part 01



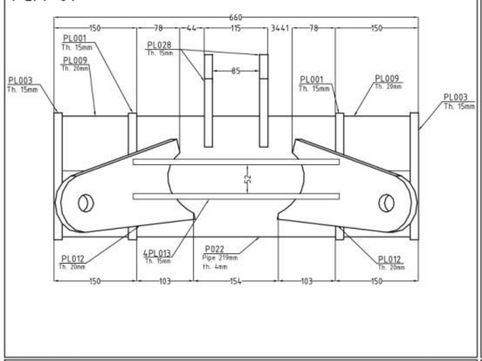
3D View Qty=1

Part 01



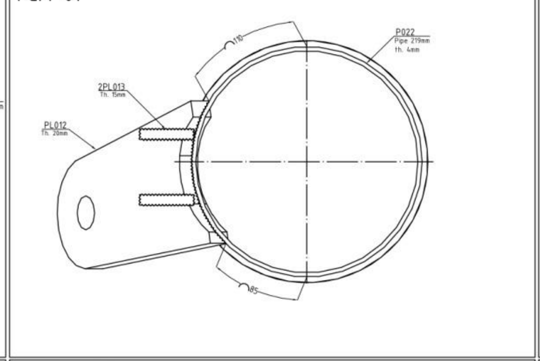
Plan View Qty=1

Part 01



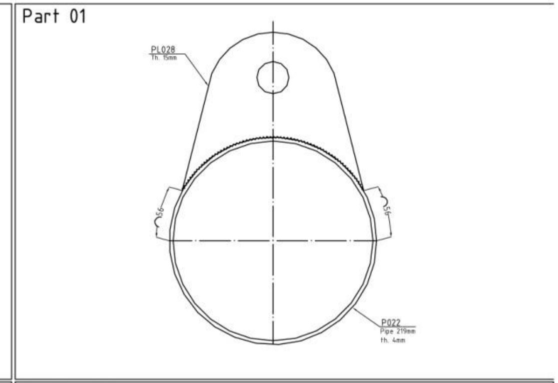
Front View Qty=1

Part 01



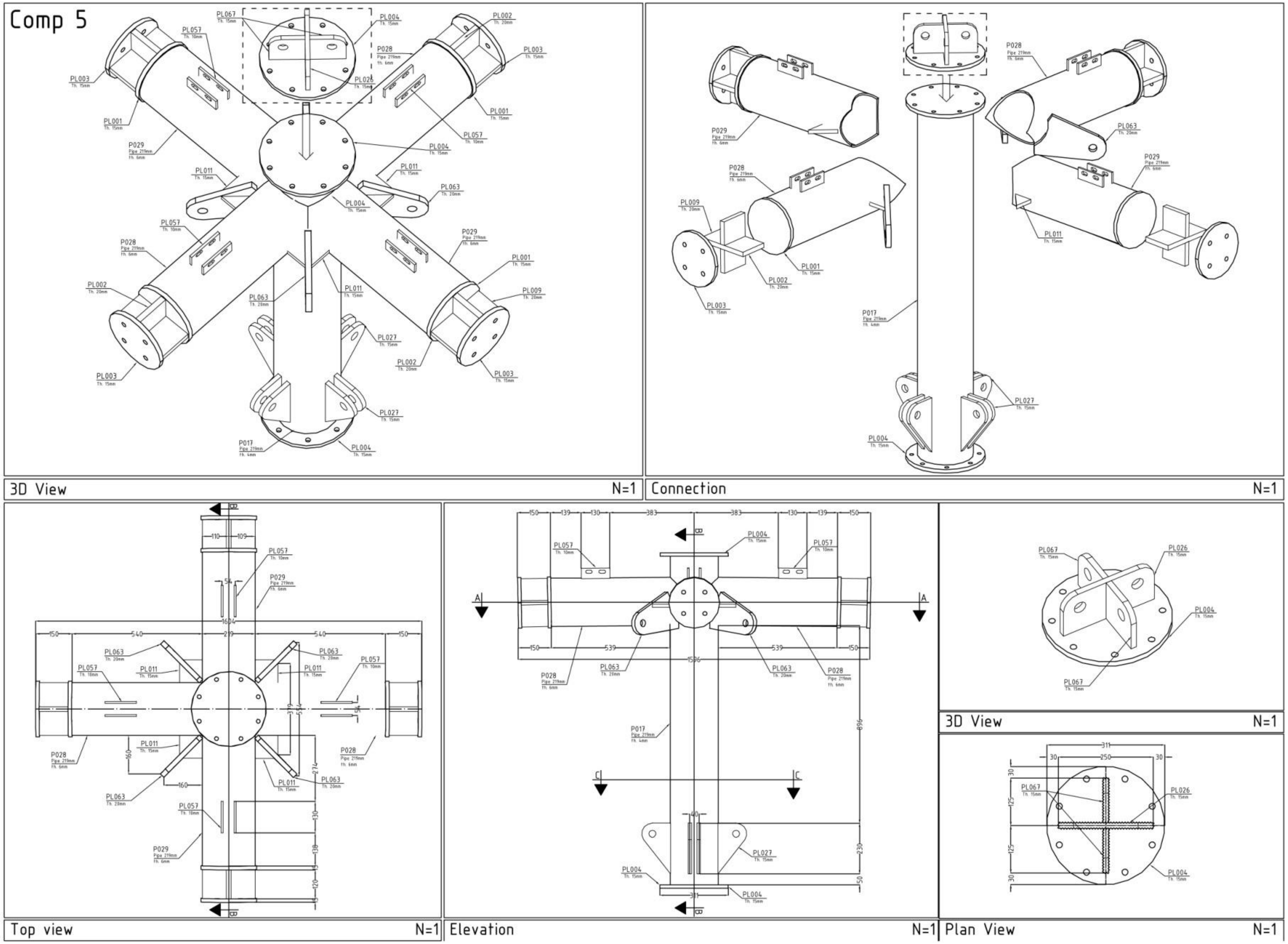
Section A.A

Part 01



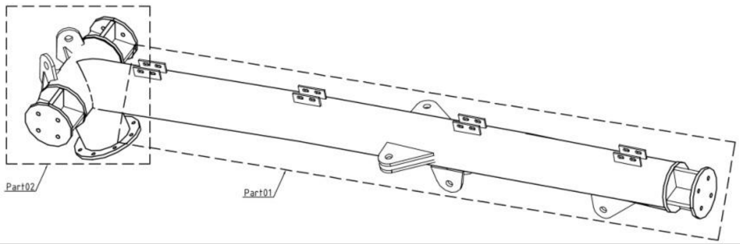
Section B.B

2-8 Shop Drawing

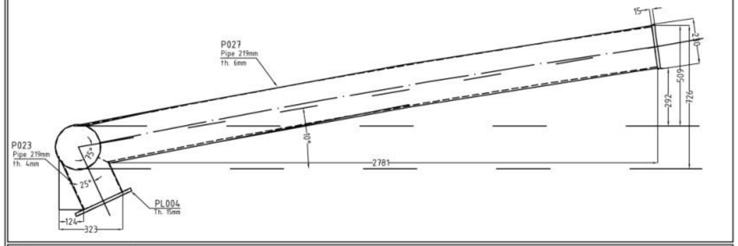


2-8 Shop Drawing

Comp 11

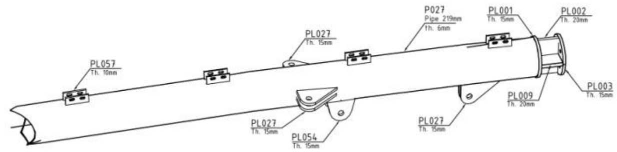


3D View Qty= 1



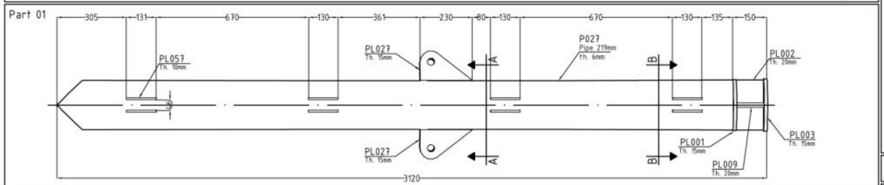
Pipe connection

Part 01



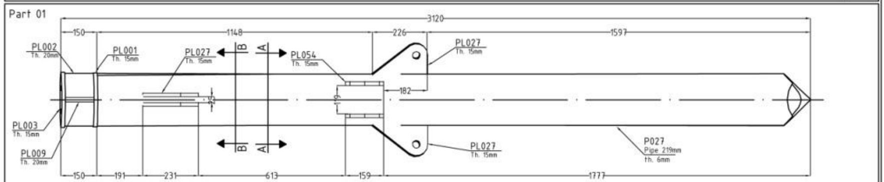
3D view Qty=1

Part 01



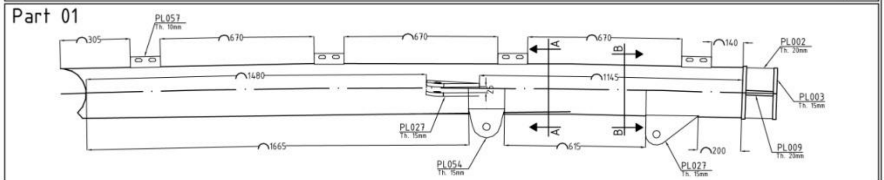
Plan view Qty=1

Part 01



Bottom View Qty=1

Part 01



Right view Qty=1

Part 01

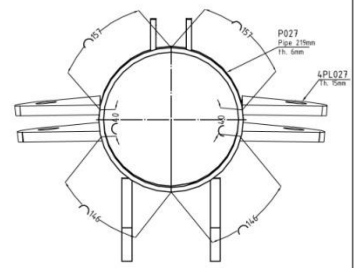


Plate 027

Section A-A

Part 01

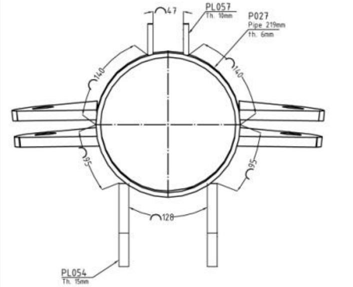
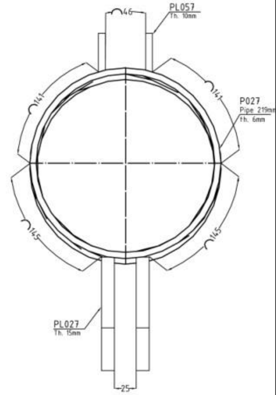


Plate 054 & 057

Section A-A

Part 01



Section B.B

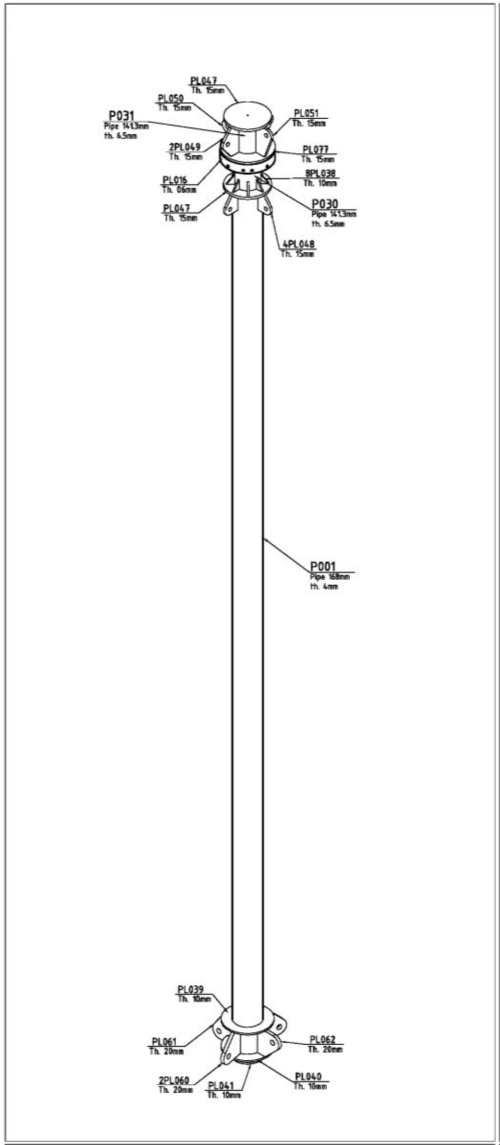
Quantity for 1 Components 11

N°	OBJECT	QTY	THICKNESS	MATERIAL	NOTE
P023	PIPE ø 219.1 mm	1	4 mm	STEEL S235	/
P022	PIPE ø 219.1 mm	1	4 mm	STEEL S235	/
P027	PIPE ø 219.1 mm	1	6 mm	STEEL S235	/
PL001	Plate PL001	3	15 mm	STEEL S235	/
PL002	Plate PL002	6	20 mm	STEEL S235	/
PL003	Plate PL003	3	15 mm	STEEL S235	/
PL004	Plate PL004	1	15 mm	STEEL S235	/
PL009	Plate PL009	3	20 mm	STEEL S235	/
PL027	Plate PL027	6	15 mm	STEEL S235	/
PL053	Plate PL053	2	15 mm	STEEL S235	/
PL054	Plate PL054	2	15 mm	STEEL S235	/
PL057	Plate PL057	8	10 mm	STEEL S235	/
PL074	Plate PL074	2	10 mm	STEEL S235	/
PL075	Plate PL075	2	10 mm	STEEL S235	/

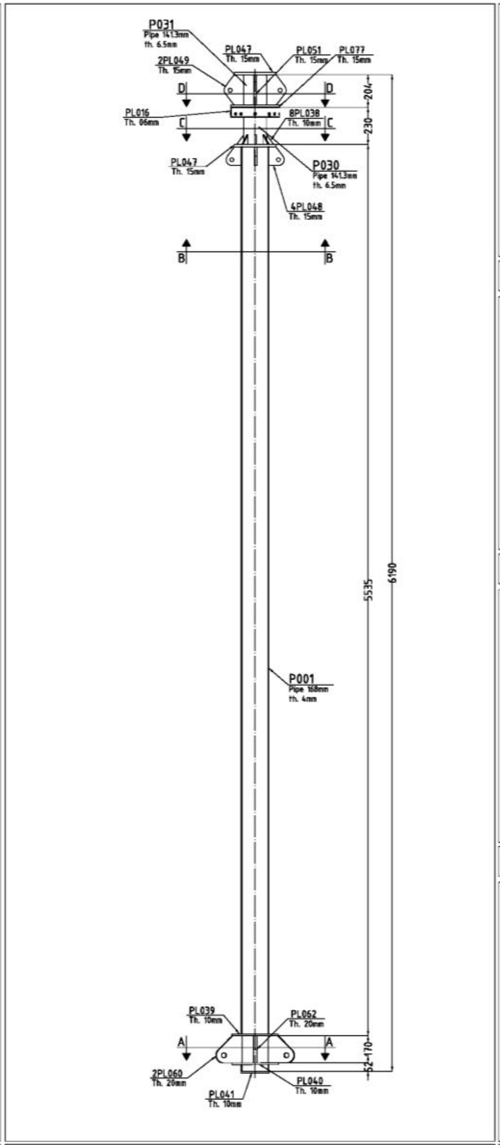
Table

2-8 Shop Drawing

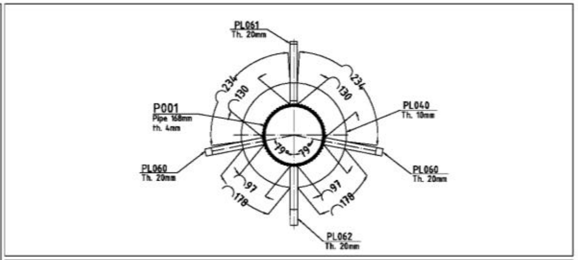
Fly Mast



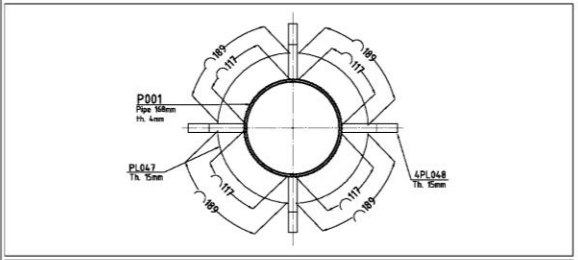
3D View Qty=4



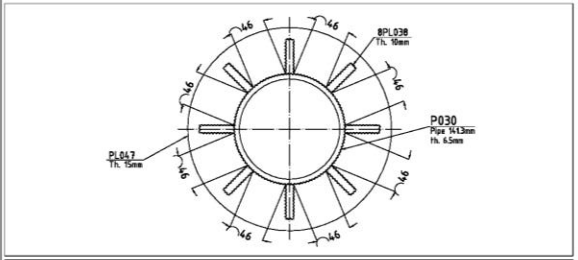
Front View Qty=4



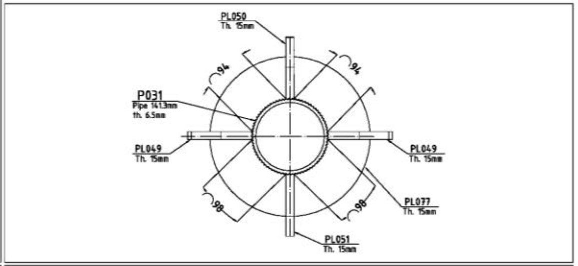
Section A.A



Section B.B



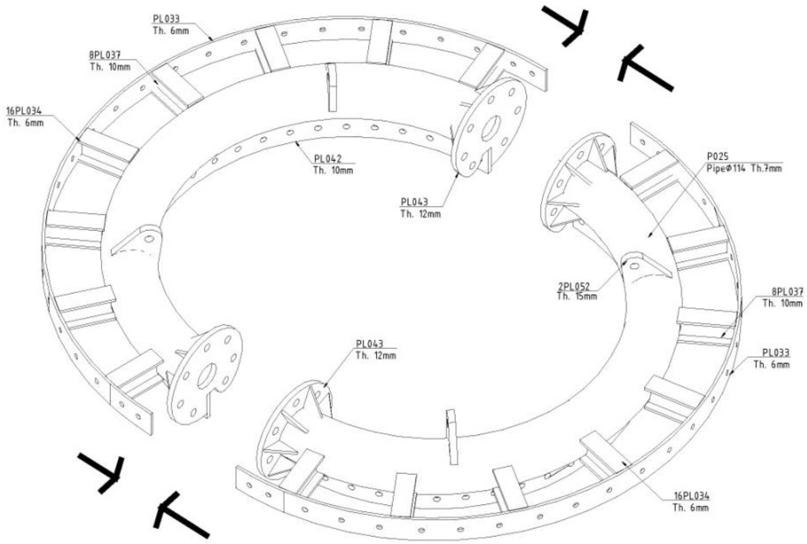
Section C.C

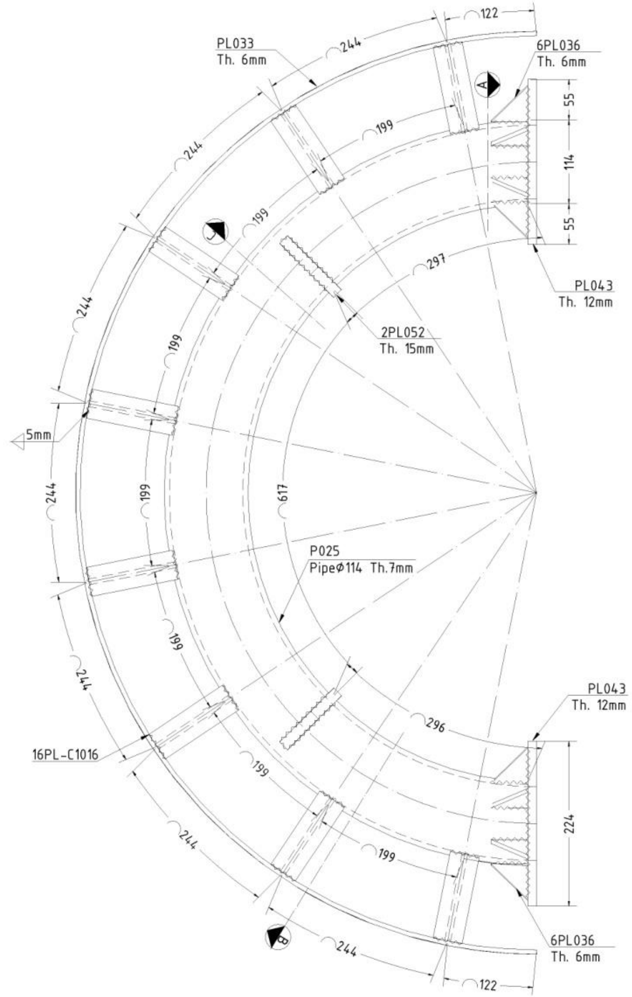


Section D.D

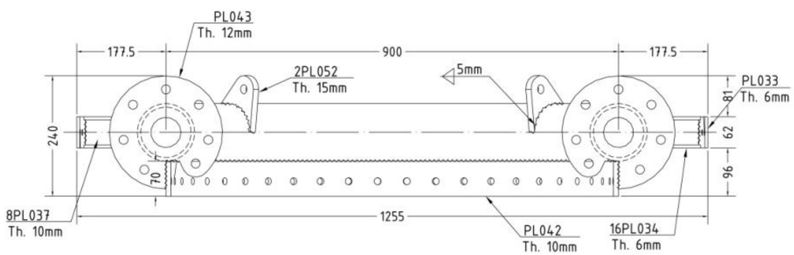
2-8 Shop Drawing

Ring

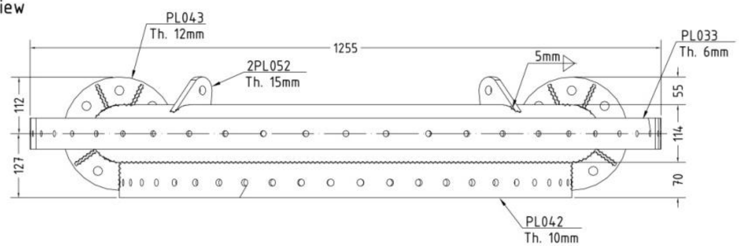




Right View



Left View



Chapter 3 :

FABRIC DESIGN

3-1 Fabric Type

Fabric Ferrari PRECONTRAINT 902S

Data Sheet

PRECONTRAINT® 902S

Technical properties	Precontraint® 902S	Standards
Yarn	1100 dtex PES HT	TERSUISSE
Weight	950 g/m² 28 oz/sqyd	EN ISO 2286-2
Width	267 cm - 105 inch	0/+2 mm
Tensile strength (warp/weft)	420/400 daN/5 cm 440/435 Lbs	EN ISO 1421 FTMS 191 A Method 5102
Tear resistance (warp/weft)	55/50 daN 60/56 Lbs	DIN 53.363 ASTM D 5733-95 Trapezoid
Adhesion	12 daN/5 cm	NF EN ISO 2411
Flame retardancy	**M2 • B1**	NFP 92.503 - DIN 4102
Surface Treatment	Formula S: calibrated PVDF alloy	
Product application	Temporary or permanent modular structures	

The technical data here above are average values with a +/- 5% tolerance.

Additional informations		
Coating thickness at the top of the yarns	300 µ	
Total thickness	0,66 mm	
Light transmission	9%	NFP 38511
White index	82%	CIE: International Light Commission
Thermal values Transmission Reflexion Absorption Shading coefficient Visible transmission Visible reflexion	ASHRAE 74 1988 Ts 7% Rs 75% As 18% g 11,5%	ISO EN 410 Ts 7% Rs 80% As 13% g 10,5% Tv 5% Rv 88%
Transmission UV	T-UV 0%	Eppley Solar & Sky UV radiometer
Global thermal conductivity*	Vertical position: U = 5,6W/sqm/°C Horizontal position: U = 6,4 W/sqm/°C	
Acoustical weakening index	15 dBA	ISO 717
Extreme working temperatures	-30°C / +70°C	in static position
Quality management system		ISO 9001
Environment management system		ISO 14001

* Those data are obtained by calculation through simulations of the average conditions of use, those values must be considered as approximation.

The buyer of our products is fully responsible for their application or their transformation concerning any possible third party. The buyer of our products is responsible for their implementation and installation according to the standards, use and customs and safety rules of the countries where they are used. Concerning the contractual warranty, please refer to the text of our warranty. The values here above mentionned are the results of tests performed in conformity with the use and customs in terms of studies, they are given as an indication in order to allow our customers to make the best use of our products. Our products are subjects to evolutions due to technical progress, we remain entitled to modify the characteristics of our products at any time. The buyer of our products is responsible to check that the here above data are still valid.

Image 70 : Fabric Data Sheet

3-2 Fabric Design

As European Design Guide for Tensile Structures shows by Testing Methods and Standards from Laboratory Blum the E module of the membrane has to be consider in Kg/m.
That because the thickness of the membrane is negligible, in fact all the values (E Module, Tensile strength and everything else) are related to the unitary thickness . When you look the pictures below, just think that the membrane has got 0.01m thickness and the values are Kg/m . The following images represent the tension inside the membrane for all the load combinations.

3-2 Fabric Design :

The membrane itself is verified in accordance with the Method of A-factor by Minte (Dissertation, Aachen, Germany, 1981). The reduction Factors (A-Factors) for the membrane material/seams/clamping are assumed as follows:

The allowable stress is defined as follow: $F_d = F_{tk}/Y_F . Y_M . A_i = F_{tk}/A_{res}$

Membrane PVC Type II : F_{tk}= Warp 8400 kg/m

Weft 8000 kg/m

[2]Where: F_d= allowable stress

F_{tk}= tensile strength

Y_F = Load Factor

Y_M = material safety coefficient for all approved materials

Y_M = 1.4 within the fabric surface and 1.5 for connections

A_i = combination of reduction factors depending on load case.

A_{res}= global safety factor defined as follow

A0: Reduction factor taking into account that the small width strip tensile test produces a higher value than the biaxial strength.

A1: Reduction factor for long-term loads, with the connection factors very dependent on seam widths.

A2: Reduction factor for pollution and degradation

A3: Reduction factor for high temperature load case

a) A-Factors for the material:

A0=1.20
A1=1.60
A2=1.20
A3=1.20

Y_M= 1.4

*Y_F= 1.5

2. European Design Guide For Tensile Surface Structure, Chapter 6,DIN 4134 and the dissertation of "Mechanical Behavior of Connections of Coated Fabrics, Page 181-183

b) A-Factors for the seams :

A0=1.20

A1=1.60

A2=1.20

A3=1.20

Y_M= 1.5

*Y_F= 1.5

* Due to the fact that the design will be done using non-factored loads, an additional global safety-factor Y_F=1.5 is considered for the design.

Permanent : A_{res}= Y_F x Y_M x A_0 x A_1 x A_2 x A_3 = 5.81/6.22(for seams)

Snow : A_{res}= Y_M x Y_F x A_0 x A_1 x A_2 = 4.84/5.18(for seams)

Wind : A_{res}= Y_M x Y_F x A_0 x A_2 = 3.23/3.46(for seams)

Design Values :

Warp Direction :

Permanent $F_d = F_{tk}/A_{res}$ = 8400/6.22 = 1350 kg/m

Snow $F_d = F_{tk}/A_{res}$ = 8400/5.18 = 1622 kg/m

Wind $F_d = F_{tk}/A_{res}$ = 8400/3.46 = 2428 kg/m

Weft Direction :

Permanent $F_d = F_{tk}/A_{res}$ = 8000/6.22 = 1286 kg/m

Snow $F_d = F_{tk}/A_{res}$ = 8000/5.18 = 1544 kg/m

Wind $F_d = F_{tk}/A_{res}$ = 8000/3.46 = 2312 kg/m

3-2 Fabric Design :

When the critical point needs an overlap of different layers of reinforce, the allowable stress will be calculated as following shown:

$fd_{n\ layers} = fd \cdot k$

Where :

$K = n - ((n-1)^2/10)$ (n = number of layers)

For 2 layers : $K = 2-((2-1)^2/10) = 1.9$

So the allowable resistance is :

fd 2 layers = fd . k = 1383*1.9 = 2628 kg/m for permanent load

fd 2 layers = fd . k = 1660*1.9 = 3154 kg/m for snow load

fd 2 layers = fd . k = 2486*1.9 = 4723 kg/m for wind load

For 3 layers : $K = 3-((3-1)^2/10) = 2.6$

So the allowable resistance is :

fd 3 layers = fd . k = 1383*2.6 = 3596 kg/m for permanent load

fd 3 layers = fd . k = 1660*2.6 = 4316 kg/m for snow load

fd 3 layers = fd . k = 2486*2.6 = 6464 kg/m for wind load

3-3 Form finding

First I imported the boundary in the program and regenerate the formfinding. Form finding has been done by using Force Density Method. Different c-value for different materials has been applied.

Warp C Value : 200 kg/m
Weft C Value : 300 kg/m

3-4 Loads

3-4-1 Self Weight :
This case takes into account the self weight of each element
Self weight of fabric Valmex type II is 0.9 kg/sqm

3-4-2 Membrane Pretension (Pm) :
For make in tension a membrane we need to put inside a pretension, this value could be change, and depends from type of material and form of structure. Cable pretension it's considered inside to this factor.

3-4-3 Snow :
The characteristic snow load considered in Mashhad is 150 kg/m^2 and the shape factor for this structure μi

The snow load is calculated with the following equation:

$$Pr = Ps \cdot Cs$$

Ps : Basic Snow Load in Mashhad (150kg/sqm)
Cs : Roof Shape Factor

Shape Factor (Cs)

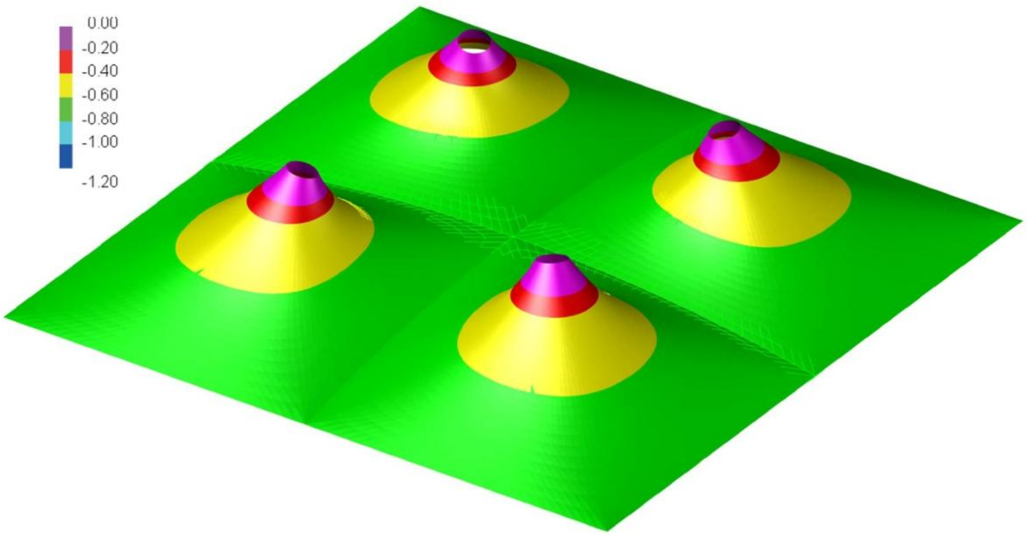


Image 71 : Shape Factor

Pr = Ps . Cs = 150 . 0.00 = 0 kg/sqm

Pr = Ps . Cs = 150 . 0.4 = 60 kg/sqm

Pr = Ps . Cs = 150 . 0.6 = 90 kg/sqm

Pr = Ps . Cs = 150 . 0.8 = 120 kg/sqm

3-4-4 Wind

The wind load is calculated by the following equation:

$$q_p = q_b . Ce(z) . c_p$$

Where:

q_p [kg/m2]: Static wind pressure.

Ce(z): Exposure factor. 2.0

q_b [kg/m2]: Basic wind pressure. $q_b = 0.005 \, . \, V^2 = 40.5$

V(wind speed considered)=90 km/h

Zone A : $q_p = -0.15 \, . \, 2 \, . \, 40.5 = -12.15$ kg/m2

Zone B : $q_p = -0.6 \, . \, 2 \, . \, 40.5 = -48.6$ kg/m2

Zone C : $q_p = -1 \, . \, 2 \, . \, 40.5 = -81$ kg/m2

Zone D : $q_p = +0.4 \, . \, 2 \, . \, 40.5 = 32.4$ kg/m2

$q_p = -0.2 \, . \, 2 \, . \, 40.5 = -16.2$ kg/m2

[1]Cp Value :

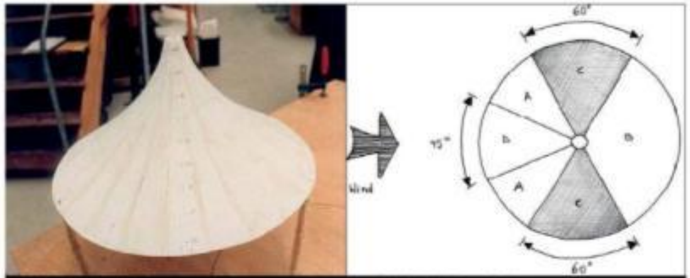


Fig. A1.1 Wind Tunnel Model Fig. A1.2 Conical C Zones Definition

Figure 15 : Zones definition Conical shape - European Design Guide for Tensile Surface Structures

EXTERNAL CP VALUES FOR CONICAL STRUCTURES		zones			
	Angle of slope of membrane to horizontal / deg.	A	B	C	D
OPEN SIDED STUCTURE	40	-0.15	-0.6	-1.0	+0.4/-0.2

Table 1 : External Cp Values for Conical Structures – European Design Guide for Tensile Surface Structures

Image 72 : Cp Value

1. European Design Guide For Tensile Surface Structure, Appendix A1,Page 261

3-5 Load combinations

COMB 1: Pretension + Self Weight

COMB 2: Pretension + Self Weight + Snow

COMB 3: Pretension + Self Weight + Wind +Y

COMB 4: Pretension + Self Weight + Wind +X

COMB 5: Pretension + Self Weight + Wind +Y + Snow

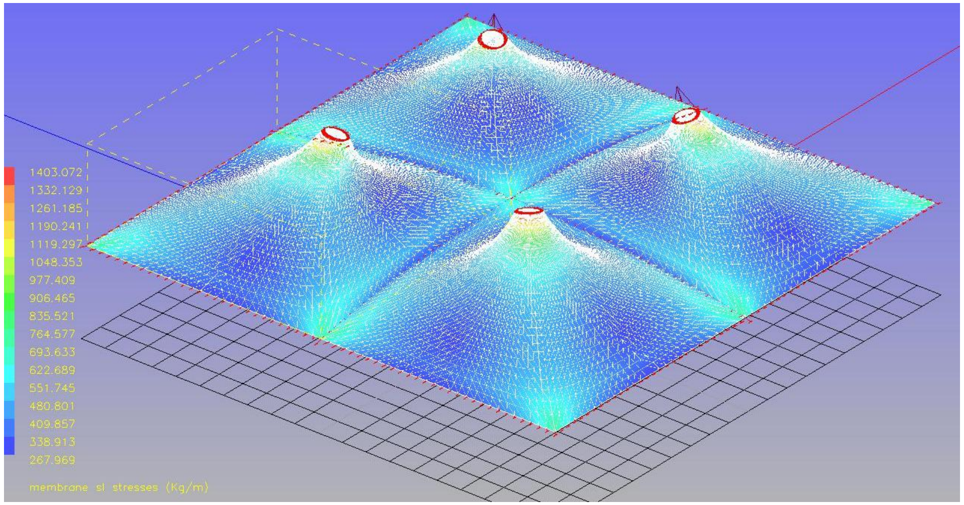
COMB 6: Pretension + Self Weight + Wind +X + Snow

3-6 Load Analysis

The stress in the membrane for the different load combination are given below:

COMB 1: Pretension + Self Weight

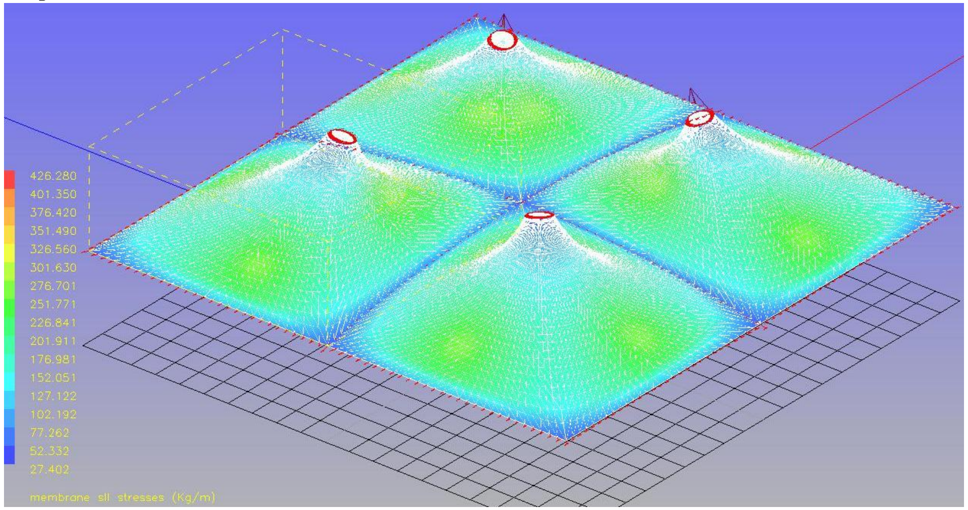
Image 73 : Membrane Stress SI-Warp (COMB 01)



The force on the zone with single layer is 640 Kg/m, lower than allowable force (fd=1350 kg/m)

The force on the critical zones is 1403 kg/m, lower than allowable force for 2 layers (fd= 2628 kg/m)

Image 74 : Membrane Stress SII-Weft (COMB 01)

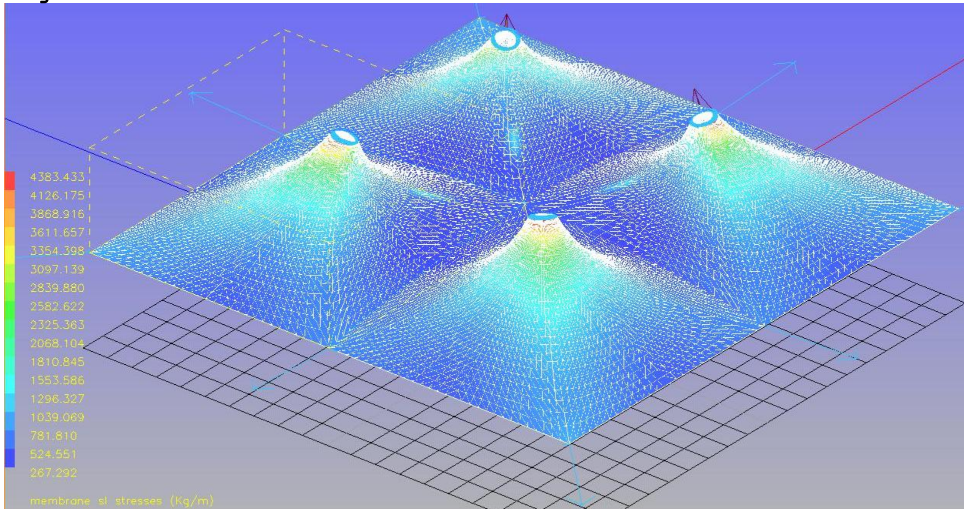


The force on the zone with single layer is 426 Kg/m, lower than allowable force (fd=1286 kg/m)

3-6 Load Analysis

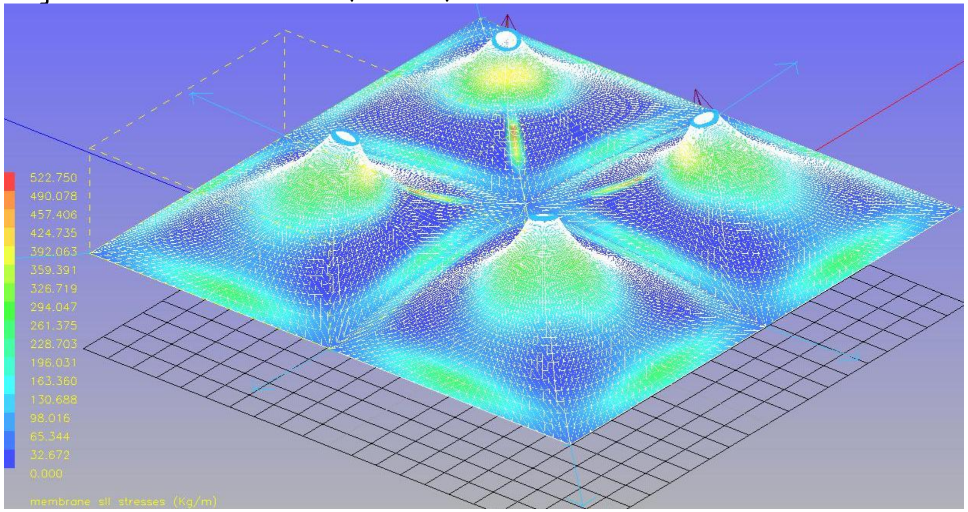
COMB 2: Pretension + Self Weight + Snow

Image 75 : Membrane Stress SI (COMB 02) :



The force on the zone with one single layer is 1553, lower than allowable force(fd=1622 kg/m)
The force on the critical zones is almost 4300, lower than allowable force for 3 Layers(fd= 4316 kg/m)

Image 76 : Membrane Stress SII (COMB 02):



The force on the zone with single layer is 522 Kg/m, lower than allowable force (fd=1544 kg/m)

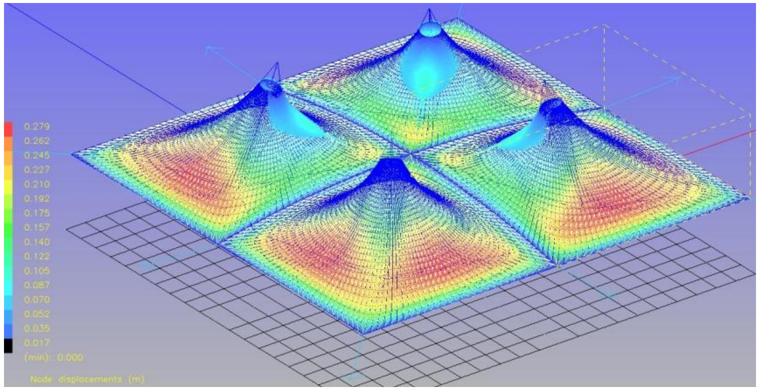
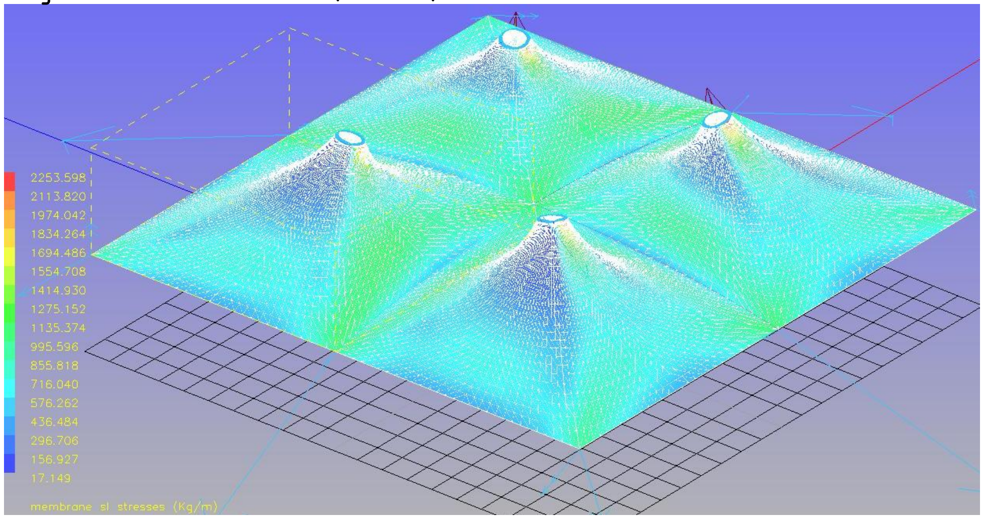


Image 77 : Membrane Deformation

3-6 Load Analysis

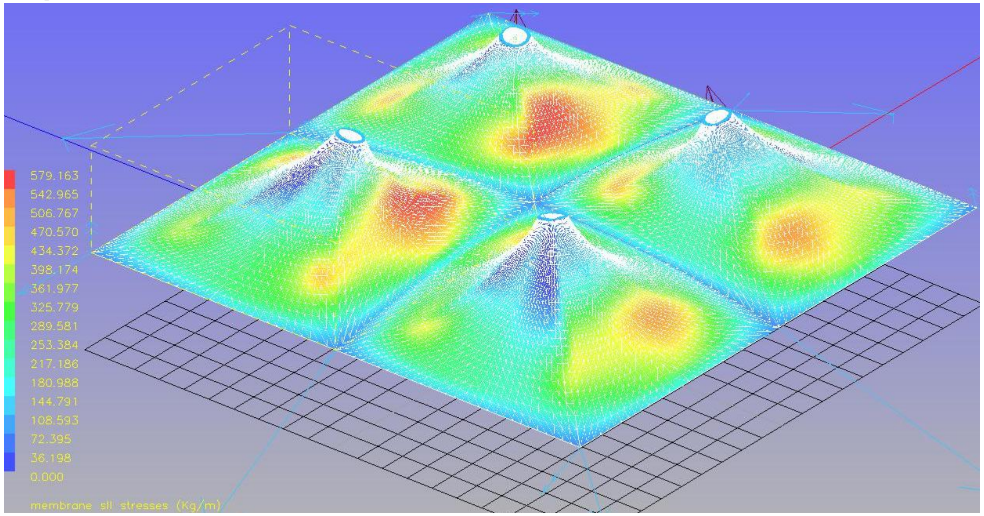
COMB 3: Pretension + Self Weight + Wind (+Y)

Image 78: Membrane Stress SI (COMB 03) :



The force on the zone with one single layer is 2253, lower than allowable force (fd=2428 kg/m)

Image 79 : Membrane Stress SII (COMB 03):



The force on the zone with single layer is 580 Kg/m, lower than allowable force (fd=2312 kg/m)

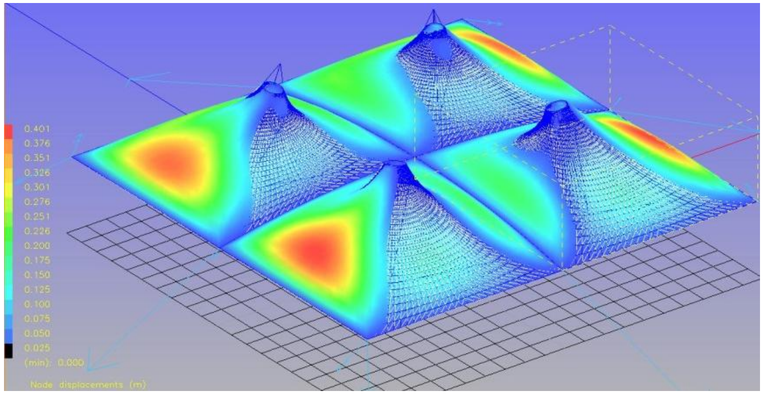
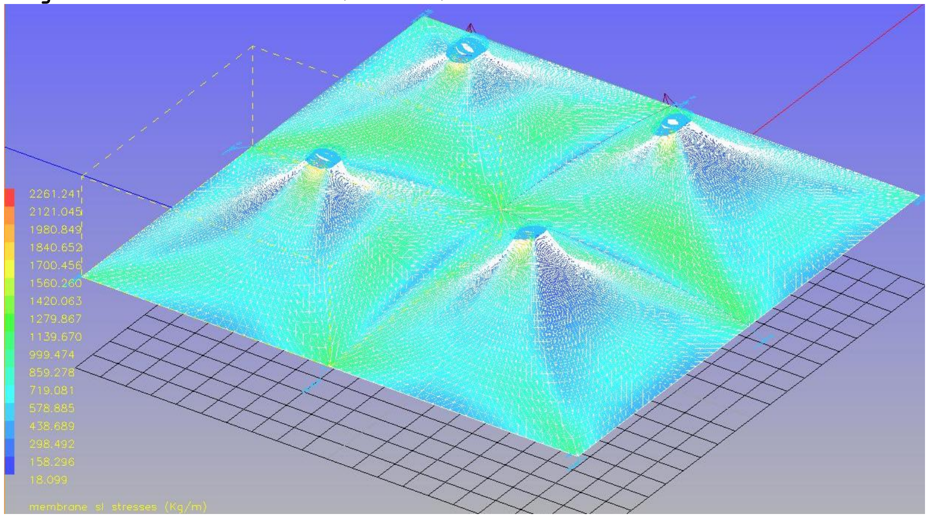


Image 80 : Membrane Deformation

3-6 Load Analysis

COMB 4: Pretension + Self Weight + Wind (+X)

image 81 : Membrane Stress SI (COMB 04) :



The force on the zone with one single layer is 2261, lower than allowable force (fd=2428 kg/m)

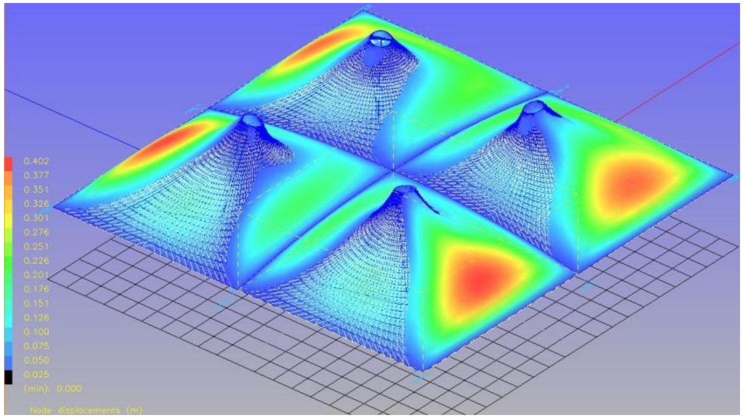
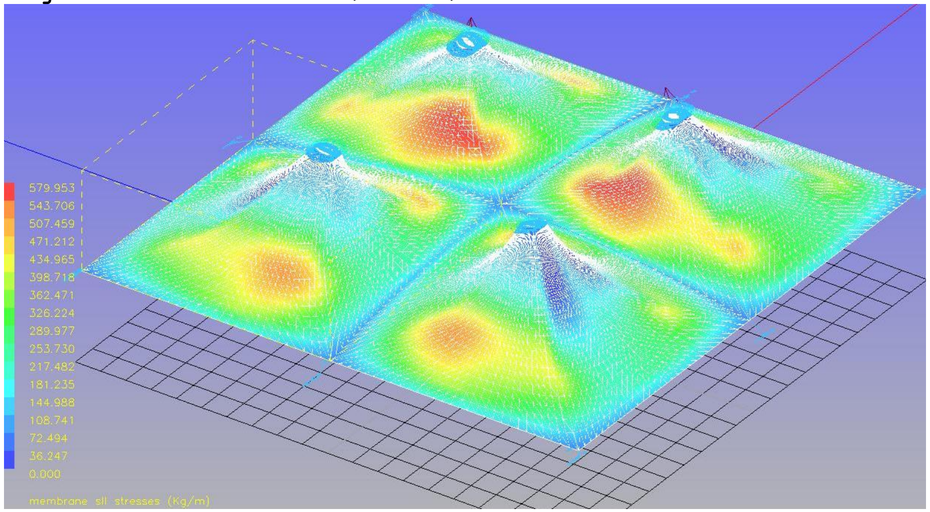


Image 83 : Membrane Deformation

Image 82 : Membrane Stress SII (COMB 04):

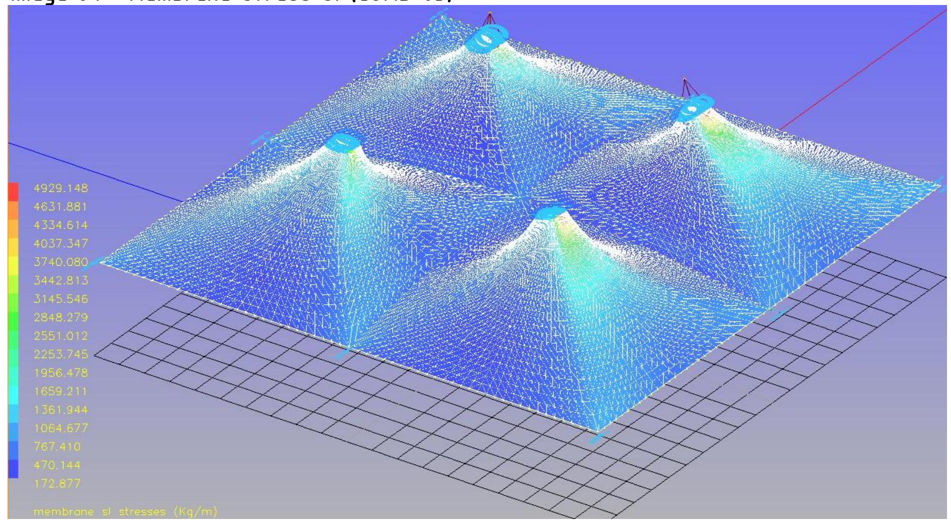


The force on the zone with single layer is 580 Kg/m, lower than allowable force (fd=2312 kg/m)

3-6 Load Analysis

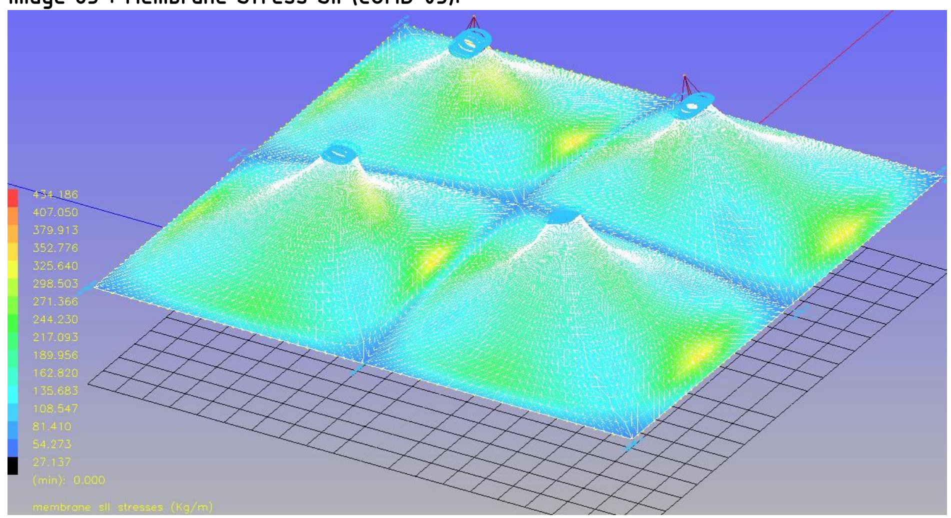
COMB 5 : Pretension + Self Weight + Wind (+Y) + Snow

Image 84 : Membrane Stress SI (COMB 05) :



The force on the zone with one single layer is 2393, lower than allowable force (fd=2428 kg/m)
The force on the critical zones is almost 4900, lower than allowable force for 3 Layers(fd= 6464 kg/m)

Image 85 : Membrane Stress SII (COMB 05):



The force on the zone with single layer is 434 Kg/m, lower than allowable force (fd=2312 kg/m)

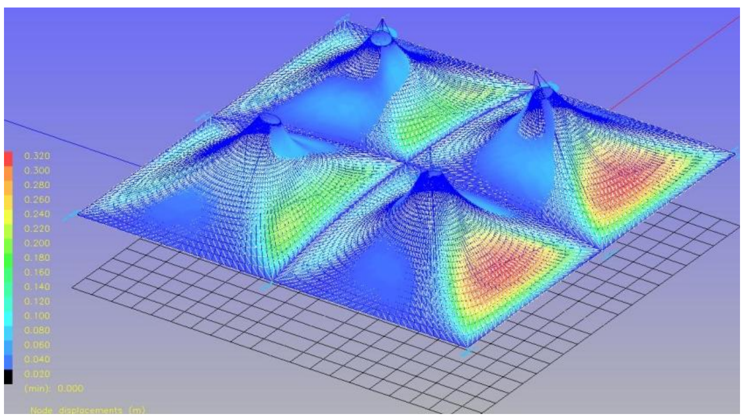
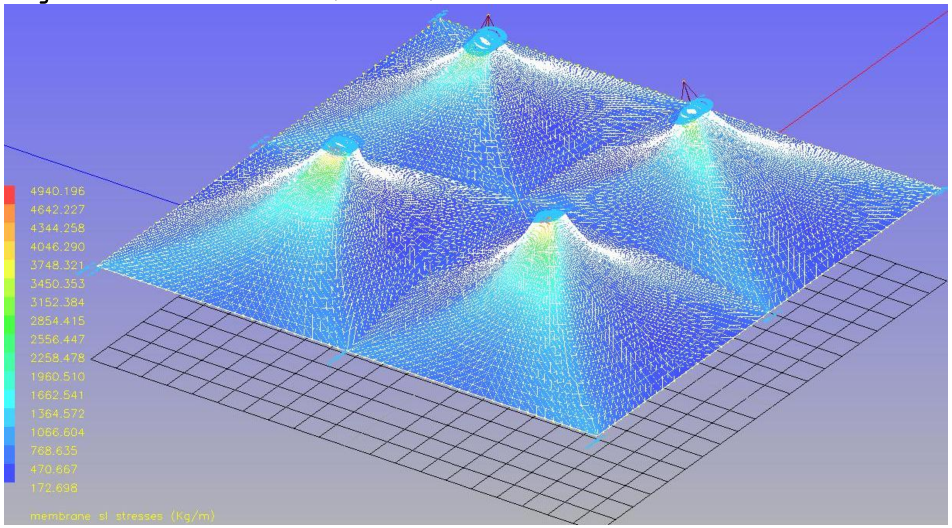


Image 86 : Membrane Deformation

3-6 Load Analysis

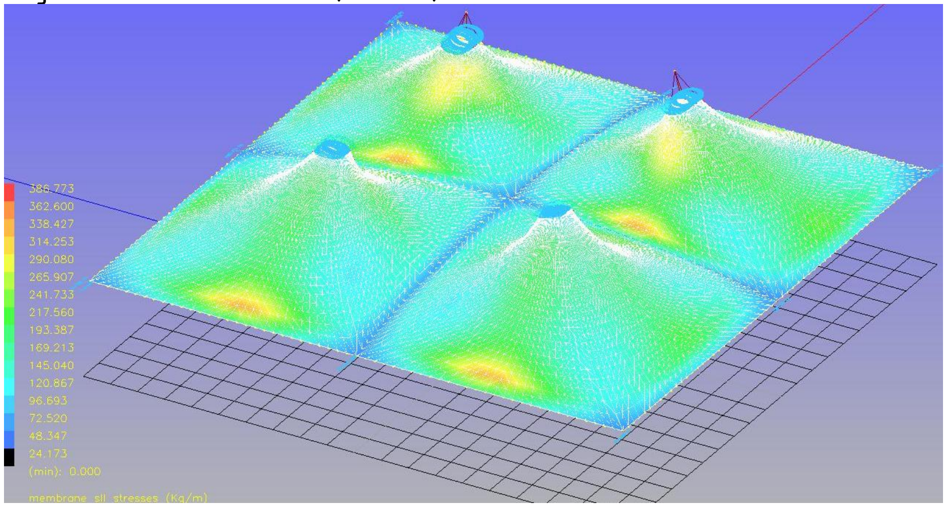
COMB 6 : Pretension + Self Weight + Wind (+X) + Snow

Image 87: Membrane Stress SI (COMB 06) :



The force on the zone with one single layer is 2854, lower than allowable force (fd=2428 kg/m)
The force on the critical zones is almost 4940, lower than allowable force for 3 Layers(fd= 6464 kg/m)

Image 88: Membrane Stress SII (COMB 06):



The force on the zone with single layer is 386 Kg/m, lower than allowable force (fd=2312 kg/m)

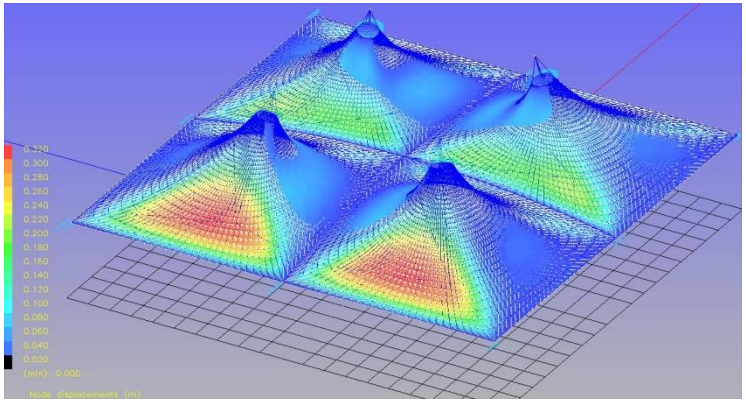


Image 89 : Membrane Deformation

3-7 Corner Reactions

COMB 01 : Pretension + Self Weight

work — Pretension Reactions:Reactions — Sat Feb 9 2013

N°	X m	Y m	Z m	Fx KN	Fy KN	Fz KN	Mx KN m	My KN m	Mz KN m	Fv KN
0	0.000	9.850	3.465	7.97e-08	-2.48e+00	7.84e-01	0.00e+00	0.00e+00	0.00e+00	2.60e+00
58	9.850	0.000	3.465	-2.47e+00	-2.92e-07	7.84e-01	0.00e+00	0.00e+00	0.00e+00	2.60e+00
87	9.850	9.850	3.465	-1.25e+00	-1.25e+00	2.63e-01	0.00e+00	0.00e+00	0.00e+00	1.78e+00
260	0.000	-9.850	3.465	-8.45e-08	2.48e+00	7.84e-01	0.00e+00	0.00e+00	0.00e+00	2.60e+00
289	9.850	-9.850	3.465	-1.25e+00	1.25e+00	2.63e-01	0.00e+00	0.00e+00	0.00e+00	1.78e+00
462	-9.850	0.000	3.465	2.47e+00	-2.91e-07	7.84e-01	0.00e+00	0.00e+00	0.00e+00	2.60e+00
491	-9.850	-9.850	3.465	1.25e+00	1.25e+00	2.63e-01	0.00e+00	0.00e+00	0.00e+00	1.78e+00
664	-9.850	9.850	3.465	1.25e+00	-1.25e+00	2.63e-01	0.00e+00	0.00e+00	0.00e+00	1.78e+00

COMB 02 : Pretension + Self Weight + Snow

work — LC1:Reactions — Sat Feb 9 2013

N°	X m	Y m	Z m	Fx KN	Fy KN	Fz KN	Mx KN m	My KN m	Mz KN m	Fv KN
0	0.000	9.850	3.465	3.46e-03	-3.75e+01	-1.77e+00	3.03e+00	-1.05e-03	-2.01e-03	3.76e+01
58	9.850	0.000	3.465	-3.74e+01	7.75e-04	-1.77e+00	-7.81e-04	-3.02e+00	-1.64e-03	3.75e+01
87	9.850	9.850	3.465	-2.68e+01	-2.69e+01	5.85e-01	-1.20e+00	1.20e+00	3.83e-02	3.80e+01
260	0.000	-9.850	3.465	1.17e-02	3.75e+01	-1.77e+00	-3.03e+00	1.10e-03	-1.93e-03	3.76e+01
289	9.850	-9.850	3.465	-2.69e+01	2.69e+01	5.85e-01	1.20e+00	1.20e+00	-4.09e-02	3.80e+01
462	-9.850	0.000	3.465	3.74e+01	4.11e-04	-1.77e+00	1.40e-03	3.02e+00	-2.47e-03	3.75e+01
491	-9.850	-9.850	3.465	2.68e+01	2.69e+01	5.85e-01	1.20e+00	-1.20e+00	3.89e-02	3.80e+01
664	-9.850	9.850	3.465	2.68e+01	-2.69e+01	5.85e-01	-1.20e+00	-1.20e+00	-4.01e-02	3.80e+01

COMB 03 : Pretension + Self Weight + Wind +Y

work — LC2:Reactions — Sat Feb 9 2013

N°	X m	Y m	Z m	Fx KN	Fy KN	Fz KN	Mx KN m	My KN m	Mz KN m	Fv KN
0	0.000	9.850	3.465	3.86e-03	-8.95e+01	3.38e+01	-8.95e+00	3.38e-04	-3.92e-04	9.57e+01
58	9.850	0.000	3.465	-7.00e+01	6.60e+00	2.95e+01	-1.04e+00	5.63e+00	-7.35e+00	7.63e+01
87	9.850	9.850	3.465	-1.53e+01	-1.63e+01	1.36e+01	-1.20e+01	9.86e+00	2.00e+00	2.62e+01
260	0.000	-9.850	3.465	1.15e-02	9.24e+01	2.57e+01	7.23e+00	3.33e-04	-4.92e-04	9.59e+01
289	9.850	-9.850	3.465	-1.57e+01	2.18e+01	1.02e+01	1.04e+01	6.30e+00	-1.35e+01	2.88e+01
462	-9.850	0.000	3.465	7.00e+01	6.60e+00	2.95e+01	-1.04e+00	-5.62e+00	7.35e+00	7.63e+01
491	-9.850	-9.850	3.465	1.57e+01	2.18e+01	1.02e+01	1.04e+01	-6.30e+00	1.35e+01	2.88e+01
664	-9.850	9.850	3.465	1.53e+01	-1.63e+01	1.36e+01	-1.20e+01	-9.86e+00	-2.01e+00	2.62e+01

COMB 04 : Pretension + Self Weight + Wind +X

work — LC3:Reactions — Sat Feb 9 2013

N°	X m	Y m	Z m	Fx KN	Fy KN	Fz KN	Mx KN m	My KN m	Mz KN m	Fv KN
0	0.000	9.850	3.465	6.62e+00	-7.00e+01	2.95e+01	-5.61e+00	1.06e+00	7.39e+00	7.62e+01
58	9.850	0.000	3.465	-8.96e+01	-4.29e-06	3.38e+01	3.18e-04	8.97e+00	-4.47e-04	9.57e+01
87	9.850	9.850	3.465	-1.63e+01	-1.53e+01	1.36e+01	-9.87e+00	1.20e+01	-2.01e+00	2.62e+01
260	0.000	-9.850	3.465	6.62e+00	7.00e+01	2.95e+01	5.62e+00	1.06e+00	-7.39e+00	7.62e+01
289	9.850	-9.850	3.465	-1.64e+01	1.53e+01	1.36e+01	9.87e+00	1.20e+01	2.01e+00	2.62e+01
462	-9.850	0.000	3.465	9.25e+01	2.29e-04	2.57e+01	3.39e-04	-7.23e+00	-4.88e-04	9.60e+01
491	-9.850	-9.850	3.465	2.18e+01	1.58e+01	1.02e+01	6.31e+00	-1.04e+01	-1.36e+01	2.88e+01
664	-9.850	9.850	3.465	2.18e+01	-1.58e+01	1.02e+01	-6.31e+00	-1.04e+01	1.36e+01	2.88e+01

3-7 Corner Reactions :

COMB 05 : Pretension + Self Weight + Wind Y + Snow

work — LC4:Reactions — Sat Feb 9 2013

N°	X m	Y m	Z m	Fx KN	Fy KN	Fz KN	Mx KN m	My KN m	Mz KN m	Fv KN
0	0.000	9.850	3.465	3.91e-03	-3.71e+01	6.11e+00	-3.77e-01	-3.18e-04	-2.70e-04	3.76e+01
58	9.850	0.000	3.465	-2.53e+01	6.26e+00	3.87e+00	-1.60e+00	-1.86e+00	-8.63e+00	2.63e+01
87	9.850	9.850	3.465	-1.55e+01	-1.81e+01	3.75e+00	-3.58e+00	2.87e+00	6.54e+00	2.42e+01
260	0.000	-9.850	3.465	1.13e-02	5.15e+01	2.44e+00	-1.40e-01	1.13e-03	-1.41e-03	5.15e+01
289	9.850	-9.850	3.465	-1.85e+01	2.64e+01	1.94e+00	3.15e+00	6.87e-01	-2.13e+01	3.23e+01
462	-9.850	0.000	3.465	2.52e+01	6.26e+00	3.87e+00	-1.60e+00	1.86e+00	8.63e+00	2.63e+01
491	-9.850	-9.850	3.465	1.85e+01	2.64e+01	1.94e+00	3.15e+00	-6.86e-01	2.13e+01	3.23e+01
664	-9.850	9.850	3.465	1.55e+01	-1.81e+01	3.75e+00	-3.58e+00	-2.87e+00	-6.54e+00	2.42e+01

COMB 06 : Pretension + Self Weight + Wind X + Snow

work — LC5:Reactions — Sat Feb 9 2013

N°	X m	Y m	Z m	Fx KN	Fy KN	Fz KN	Mx KN m	My KN m	Mz KN m	Fv KN
0	0.000	9.850	3.465	6.29e+00	-2.53e+01	3.86e+00	1.87e+00	1.61e+00	8.68e+00	2.63e+01
58	9.850	0.000	3.465	-3.71e+01	4.26e-04	6.10e+00	1.30e-04	3.78e-01	2.99e-04	3.76e+01
87	9.850	9.850	3.465	-1.81e+01	-1.56e+01	3.75e+00	-2.87e+00	3.58e+00	-6.50e+00	2.42e+01
260	0.000	-9.850	3.465	6.30e+00	2.53e+01	3.86e+00	-1.87e+00	1.61e+00	-8.68e+00	2.63e+01
289	9.850	-9.850	3.465	-1.81e+01	1.56e+01	3.75e+00	2.87e+00	3.58e+00	6.50e+00	2.42e+01
462	-9.850	0.000	3.465	5.14e+01	8.92e-04	2.43e+00	1.39e-03	1.43e-01	-1.74e-03	5.15e+01
491	-9.850	-9.850	3.465	2.64e+01	1.85e+01	1.94e+00	6.88e-01	-3.15e+00	-2.12e+01	3.23e+01
664	-9.850	9.850	3.465	2.64e+01	-1.85e+01	1.94e+00	-6.87e-01	-3.15e+00	2.12e+01	3.23e+01

3-8 Patterning:

Considering the selected fabric roll width (2.67m) I did radial division.

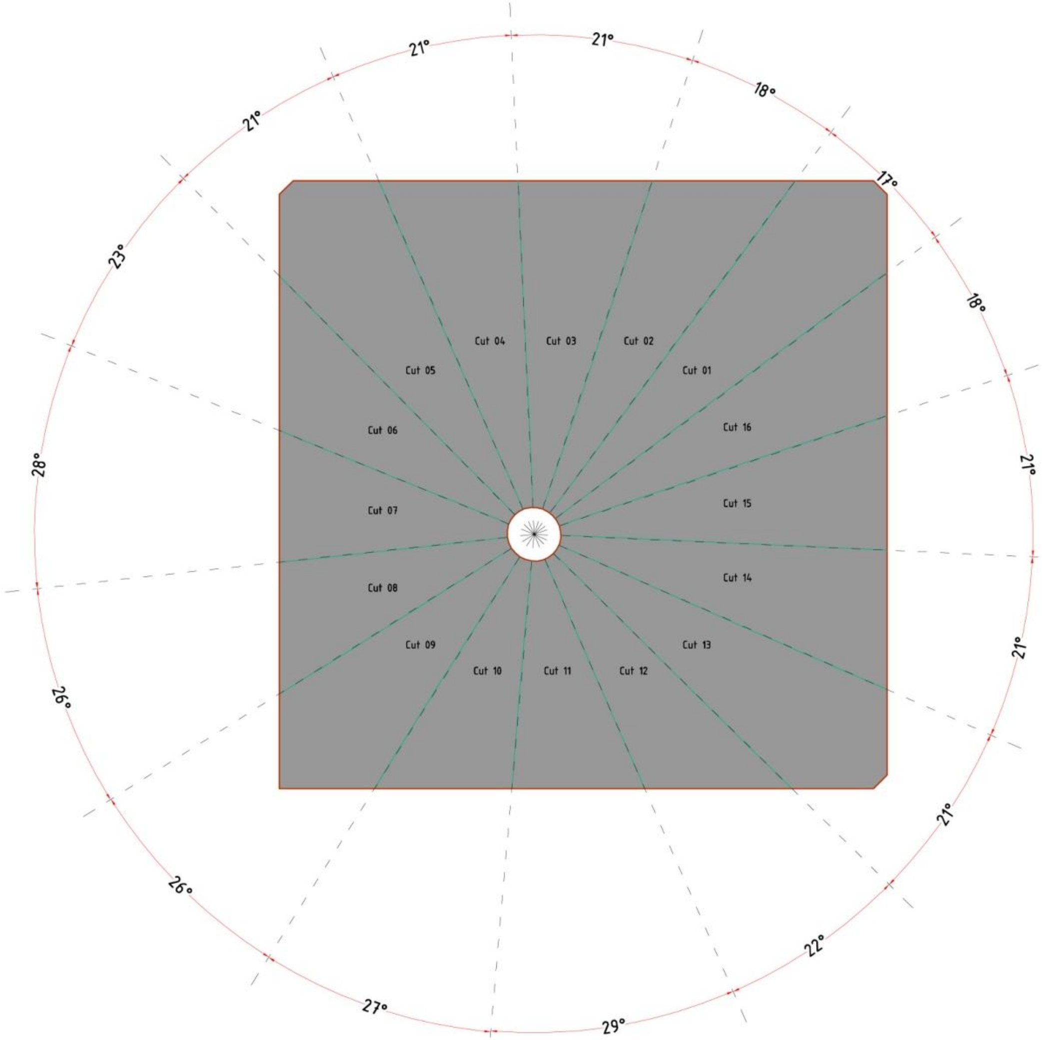


Image 90 : Radial Division

Cause I have a symmetric structure in both horizontal and vertical axis I could do the patterning of one quadrant and make four pieces of each pattern.

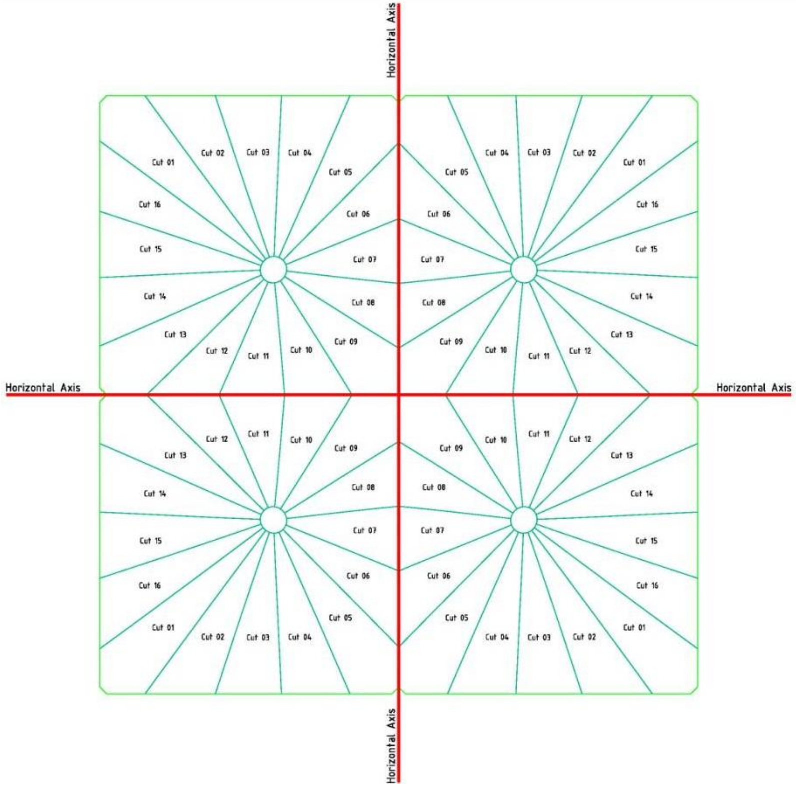


Image 91 : Isometric shape

3-8-1 Geodetic Lines

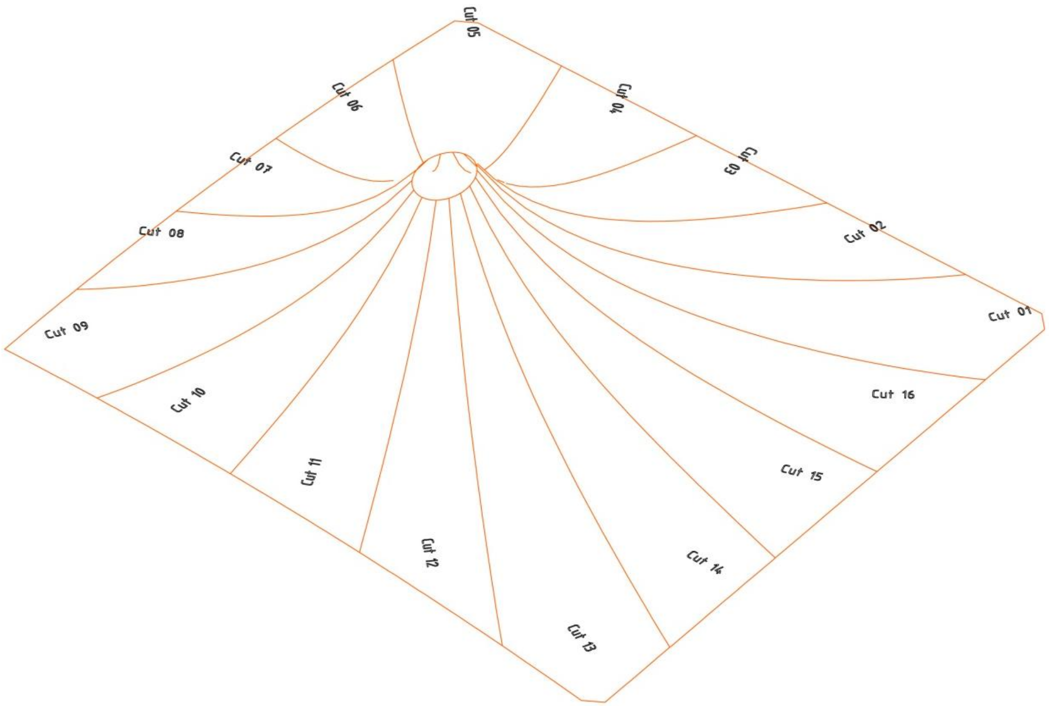


Image 92 : Geodetic Lines

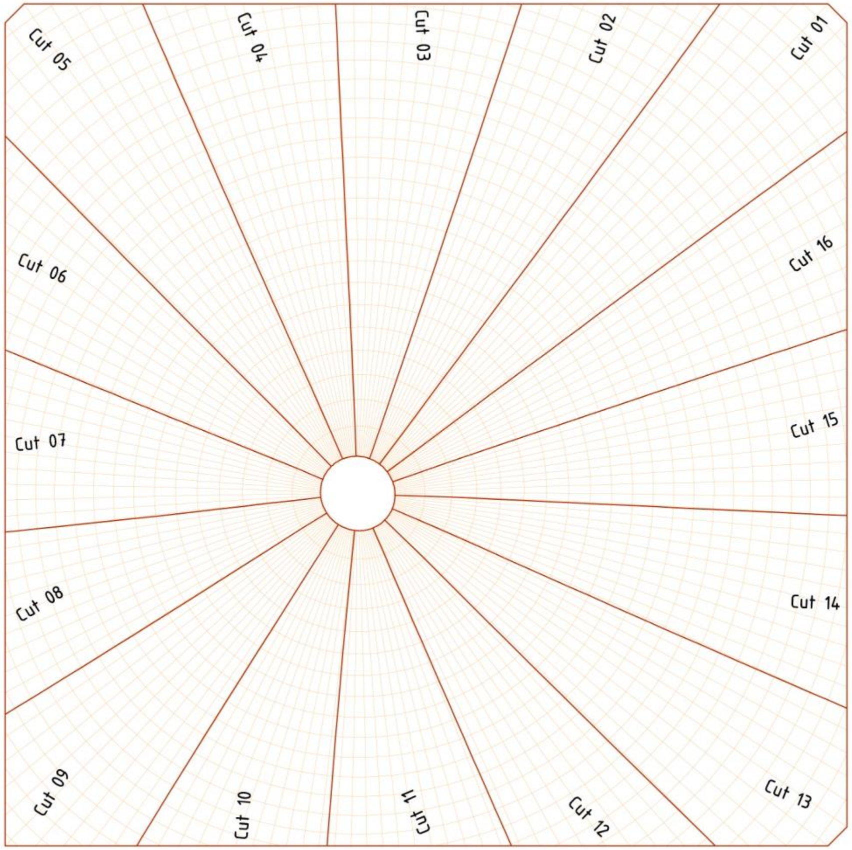


Image 93 : Geodetic Lines

3-8-2 Primary Cuts

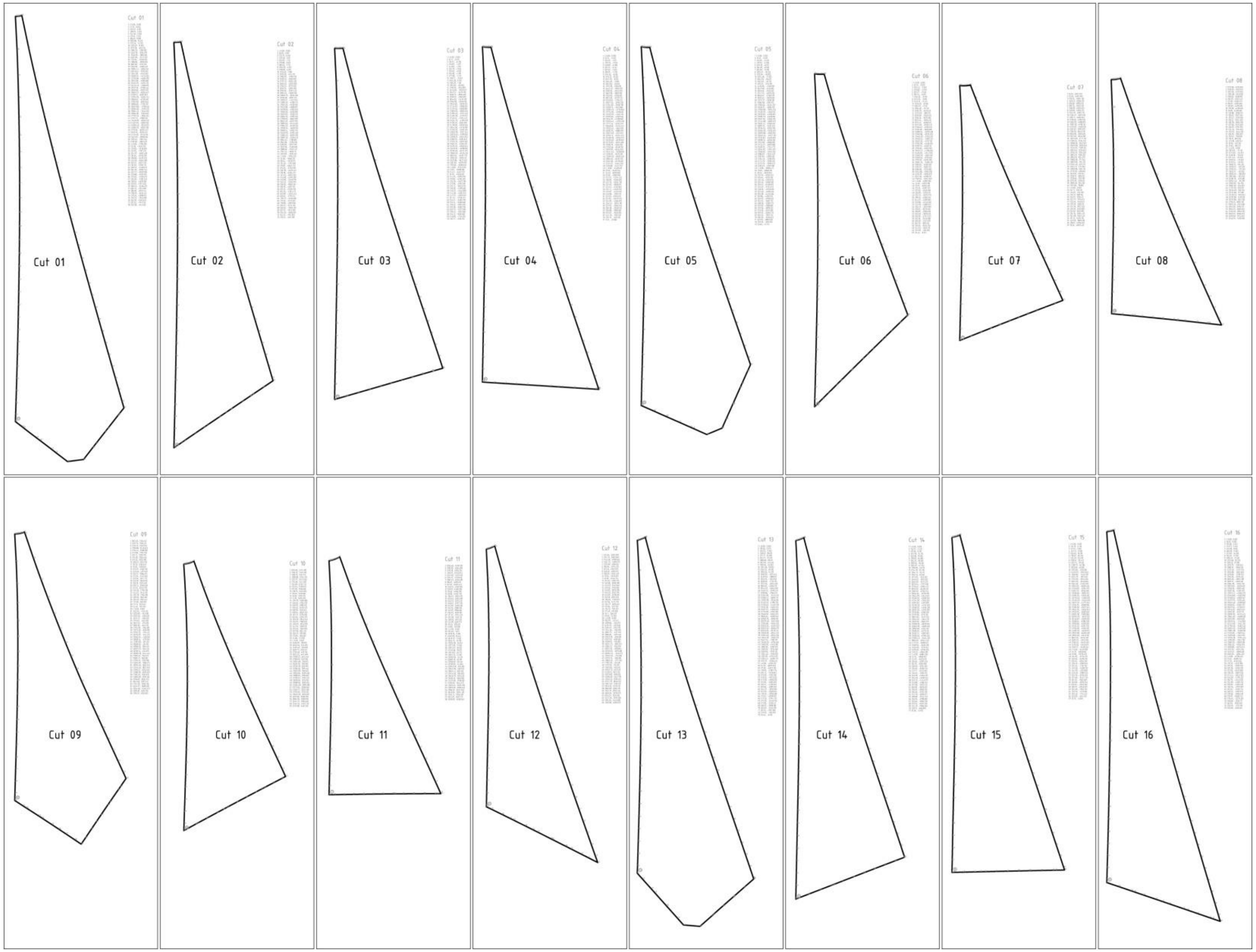


Image 94 : Primary Cuts

3-8-2 Primary Cuts

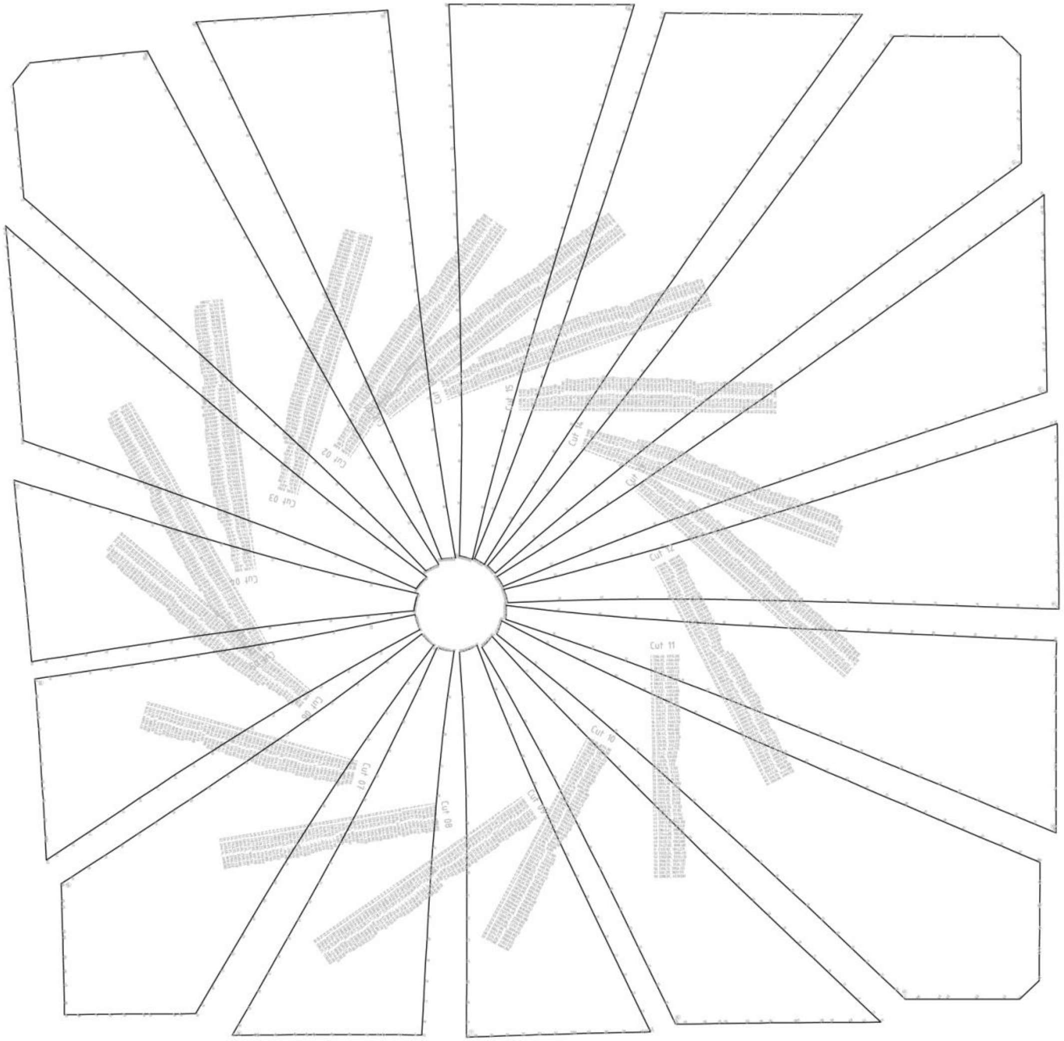


Image 95 : Primary Cuts

3-8-3 Star Reinforces :

Considering the load aggregation on top part of cones (that was shown in Forten analysis images) ,we needed to have 2 layers of reinforcement on those parts and for making reinforcements and their shadow under the membrane more beautiful we drawn them in a shape that after welding them together they seem like a star.

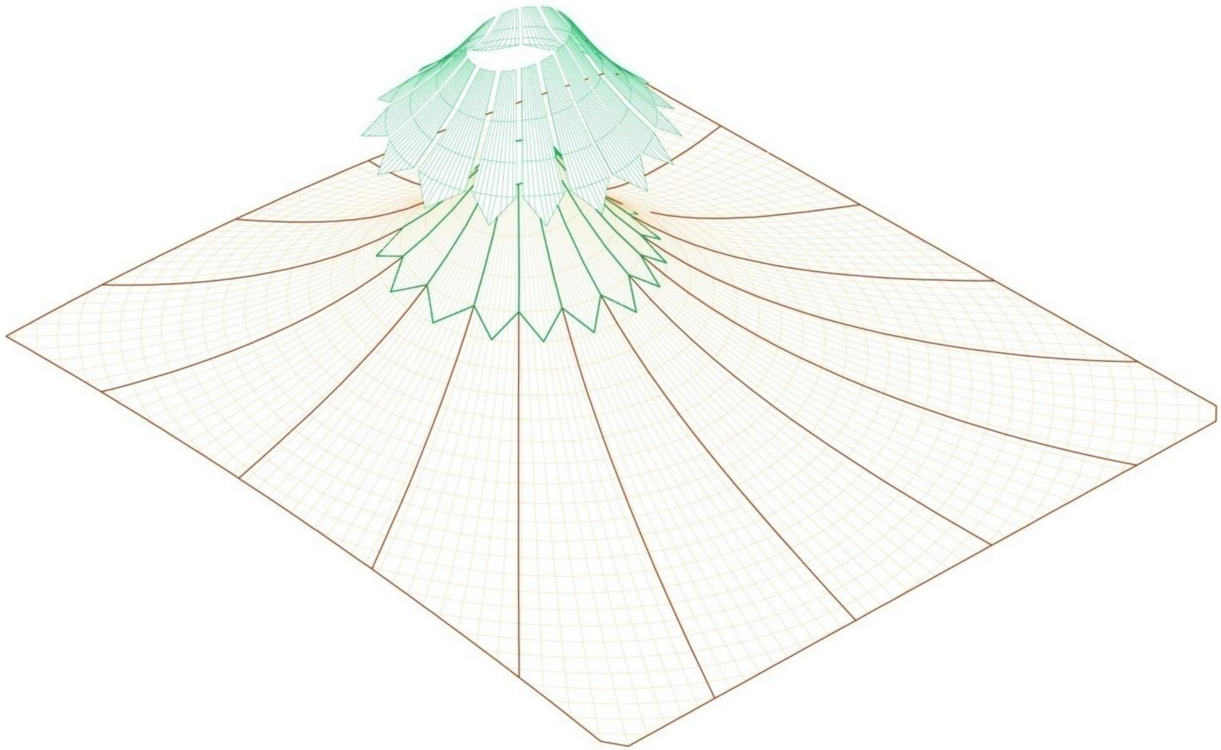


Image 96 : Star Reinforces

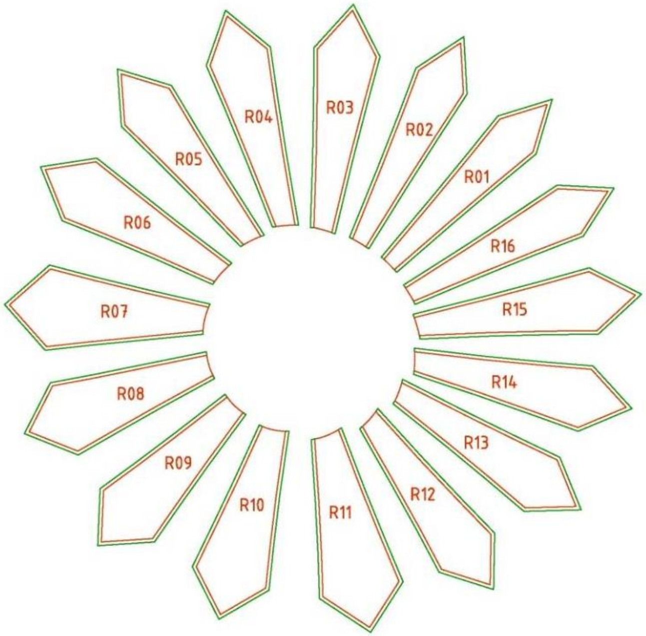


Image 97 : Star Reinforces

3-8-4 Compensation :

Looking at the bi-axial tests, and knowing that contrary to other types of fabrics, compensation values for both warp and wefts in Ferrari pre-contraint 902S are very similar. According to pretension value (640 kg/m) and considering the biaxial test table The compensation values are 0.55% in both warp and weft directions

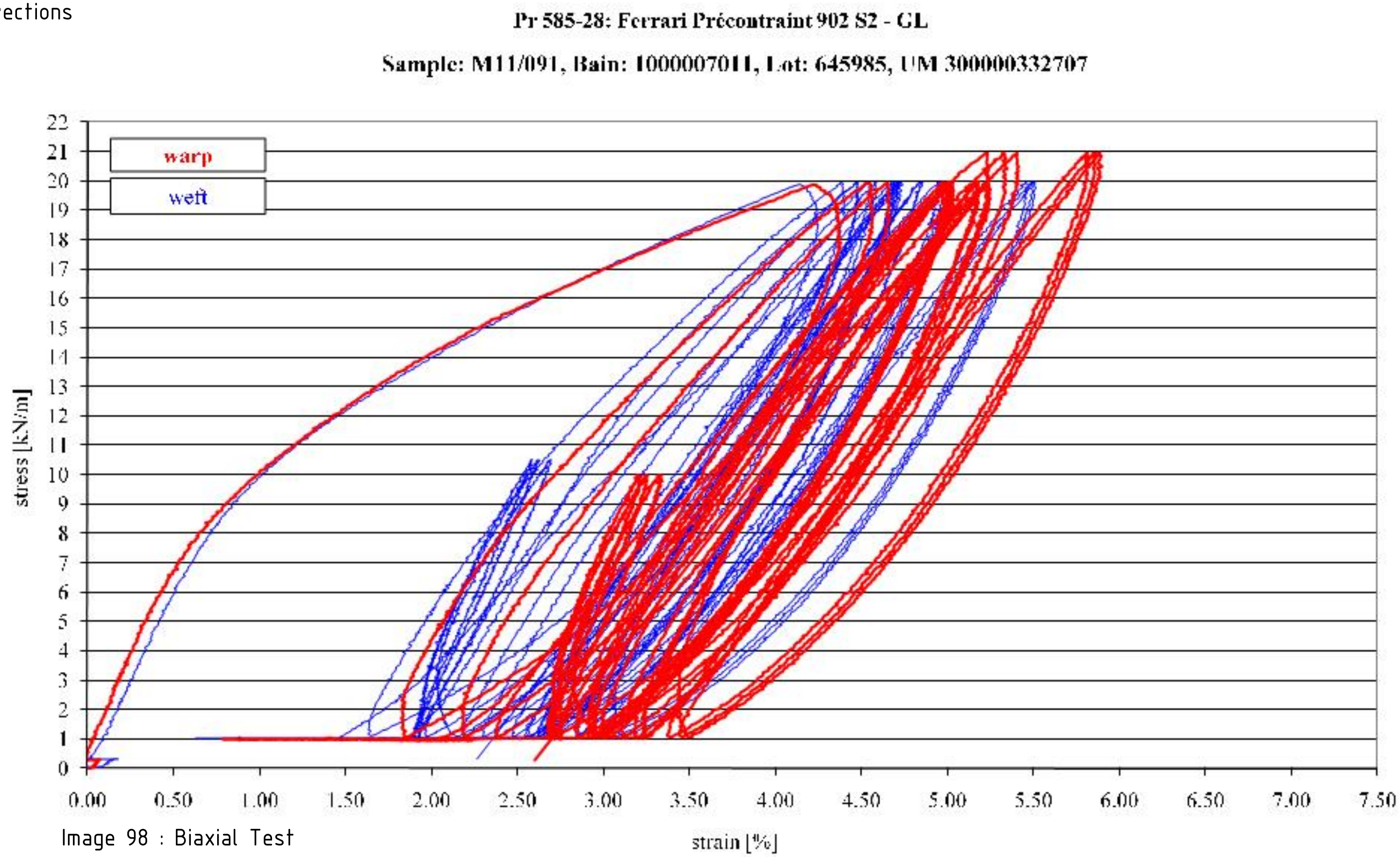


Image 98 : Biaxial Test

3-8-5 Decompensation :

We have fixed edges at the connection of fabrics to the rings ,so we have decompensation in top part of each highpoint.

3-8-6 Compensated Cuts

Compensation Value:

Warp = 0.55%

Weft = 0.55%

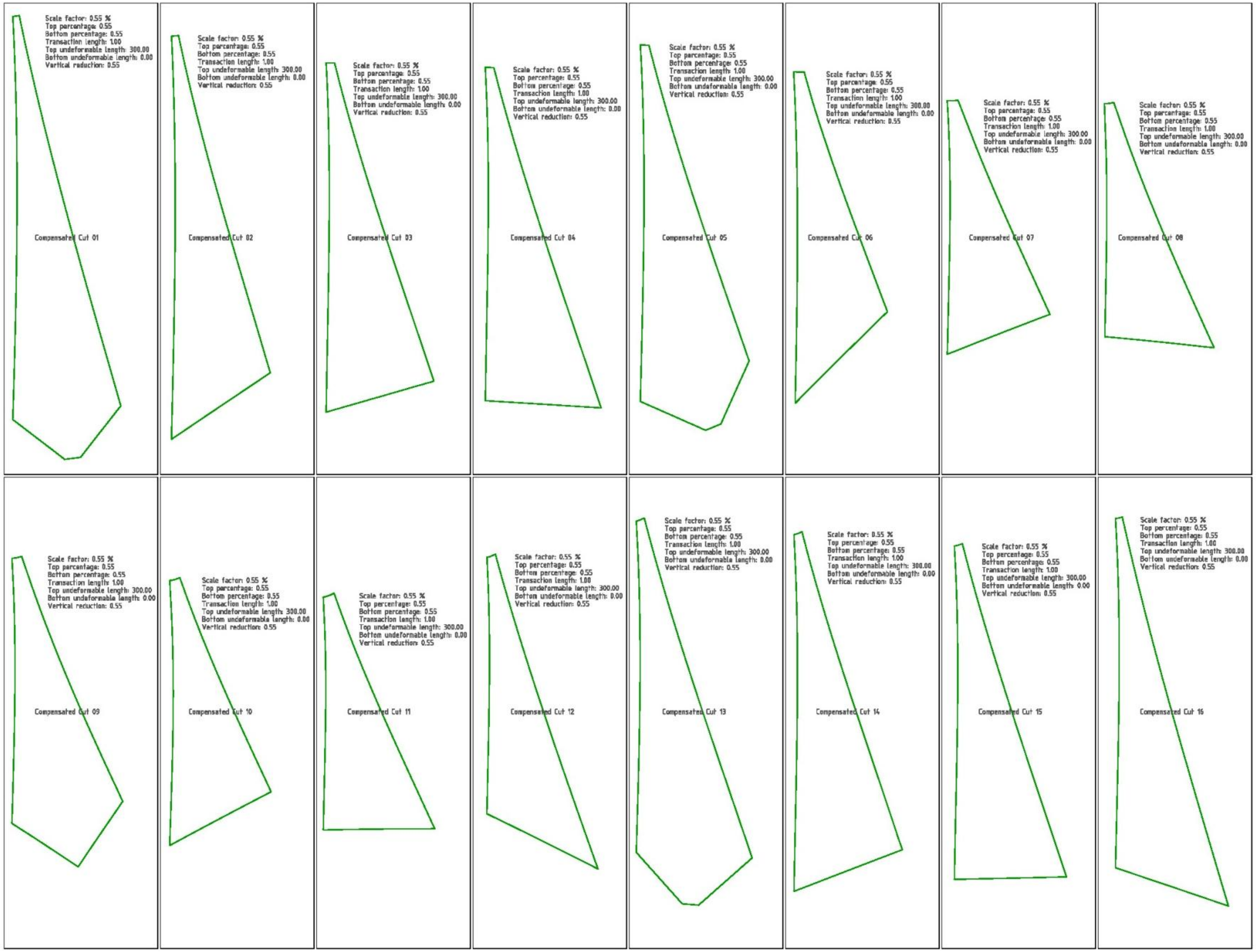


Image 99 : Compensated Cuts

3-8-7 Final Cuts :

Key Plan :

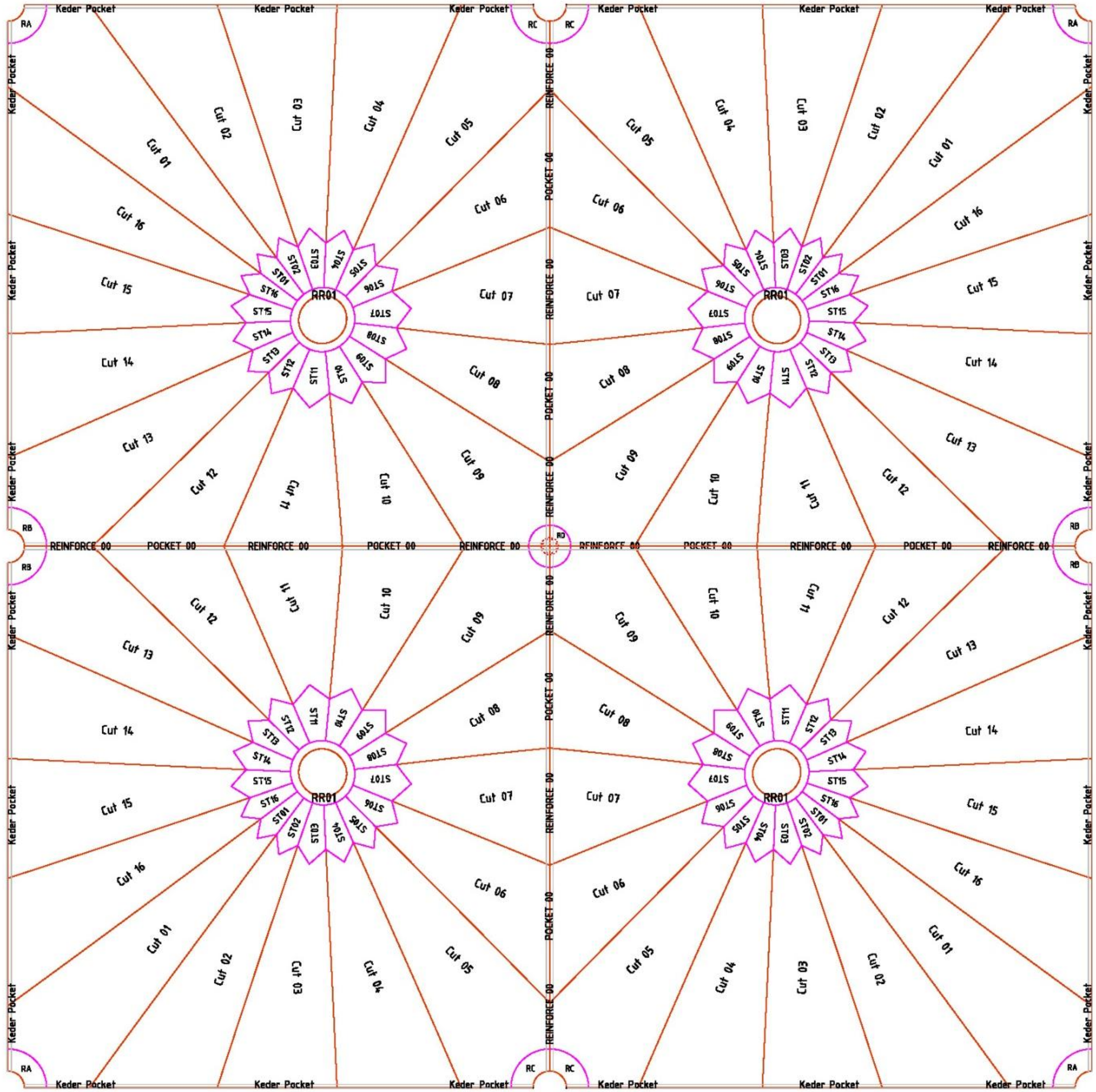


Image 100: Pattern Key Plan

3-8-7 Final Cuts :

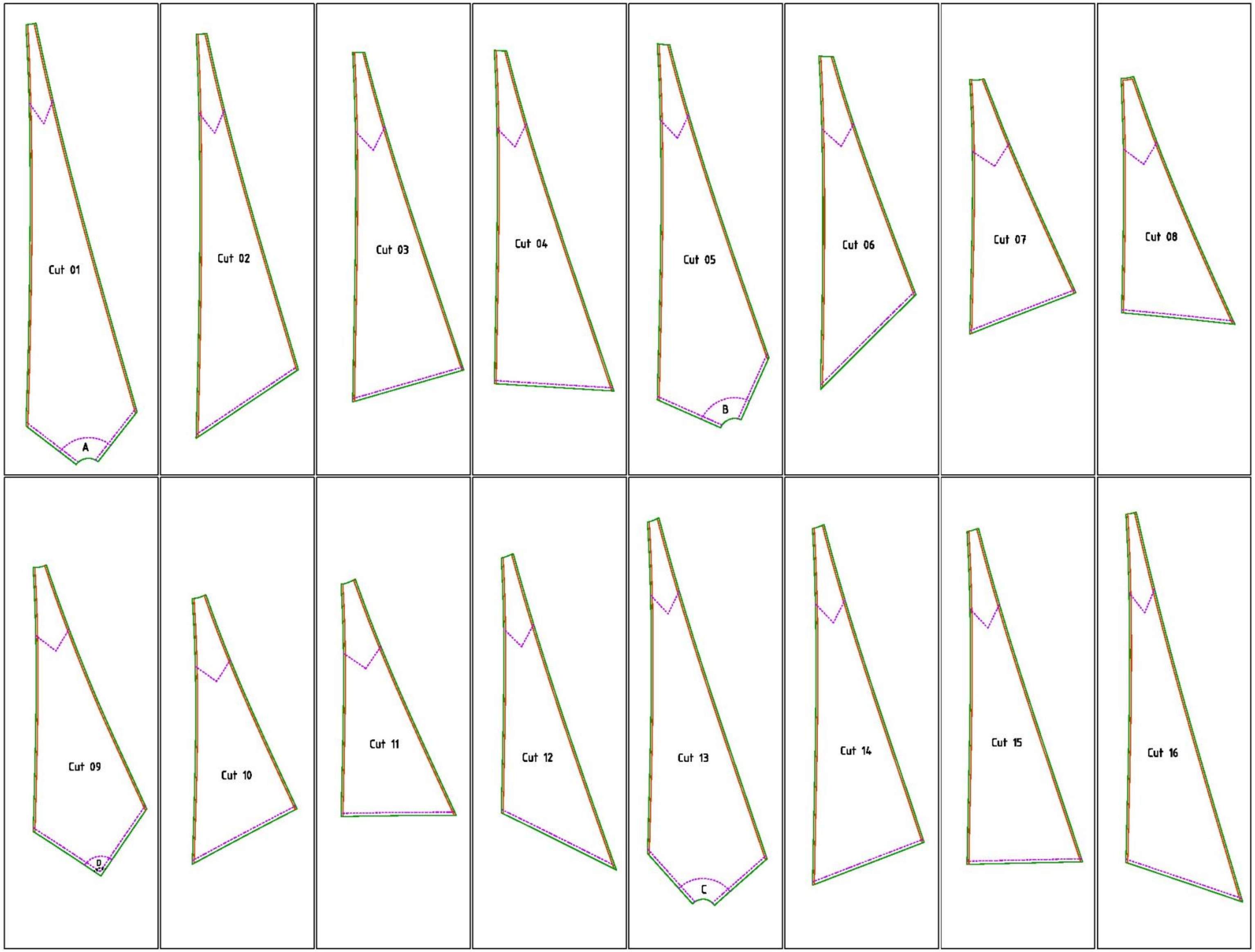


Image 101: Final Cuts

3-8-7 Final Cuts :

Reinforcement and Corners :

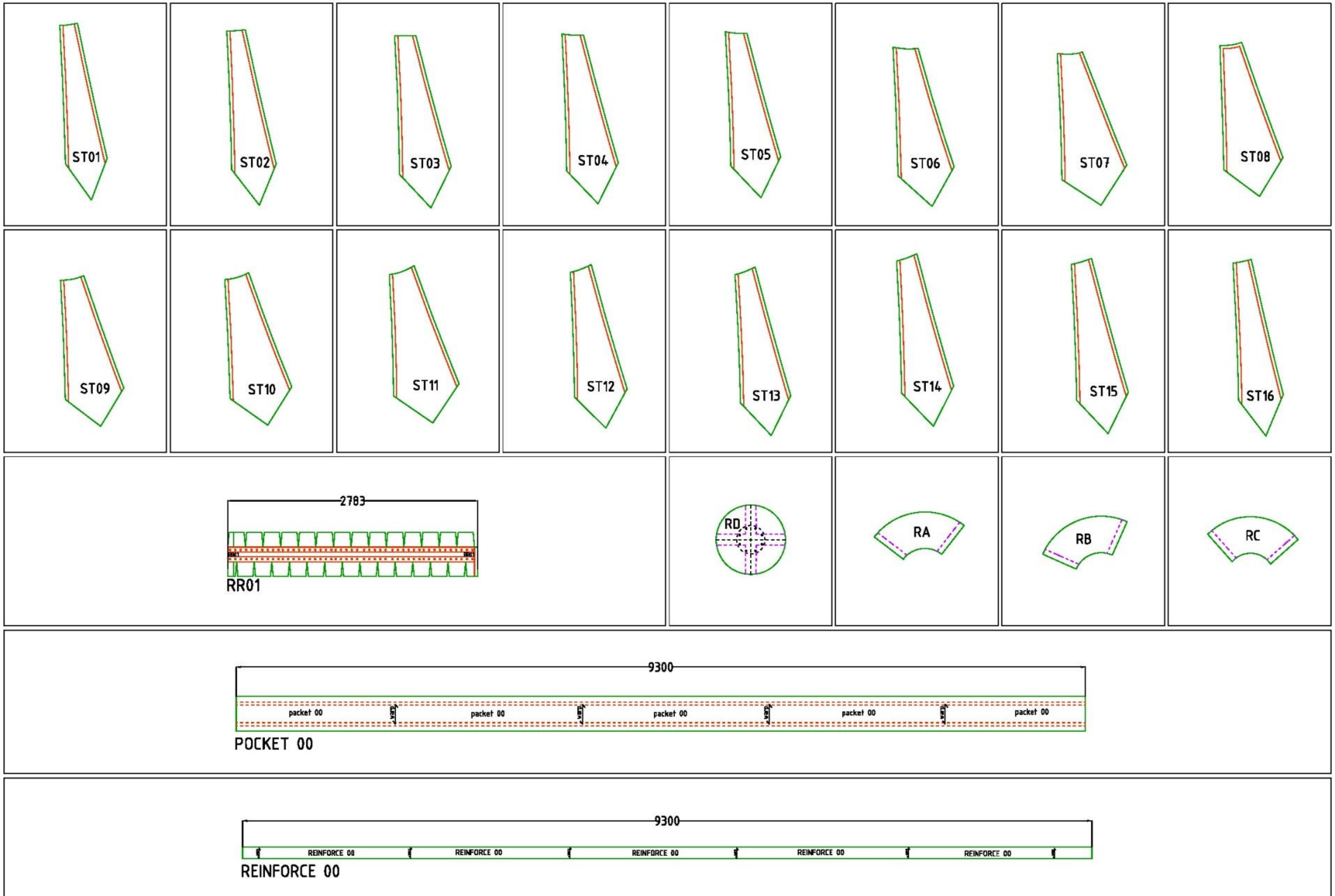


Image 102: Pockets and Reinforcements

3-8-8 Plot

Cutting Patterns are .first plotted 1:1 on paper rolls with 900mm width and variable lengths.

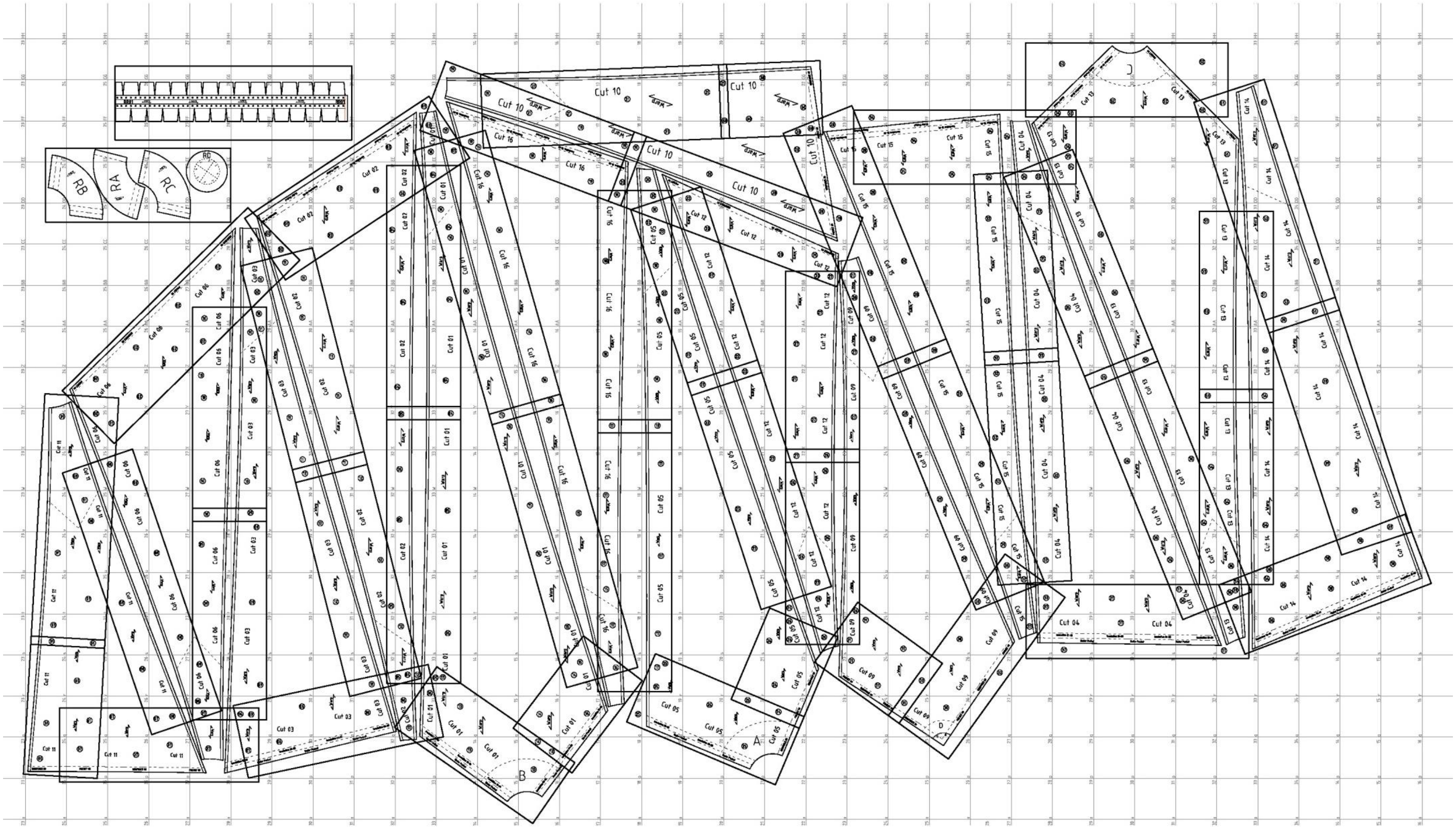


Image 103: Fabric Plot

3-8-8 Plot

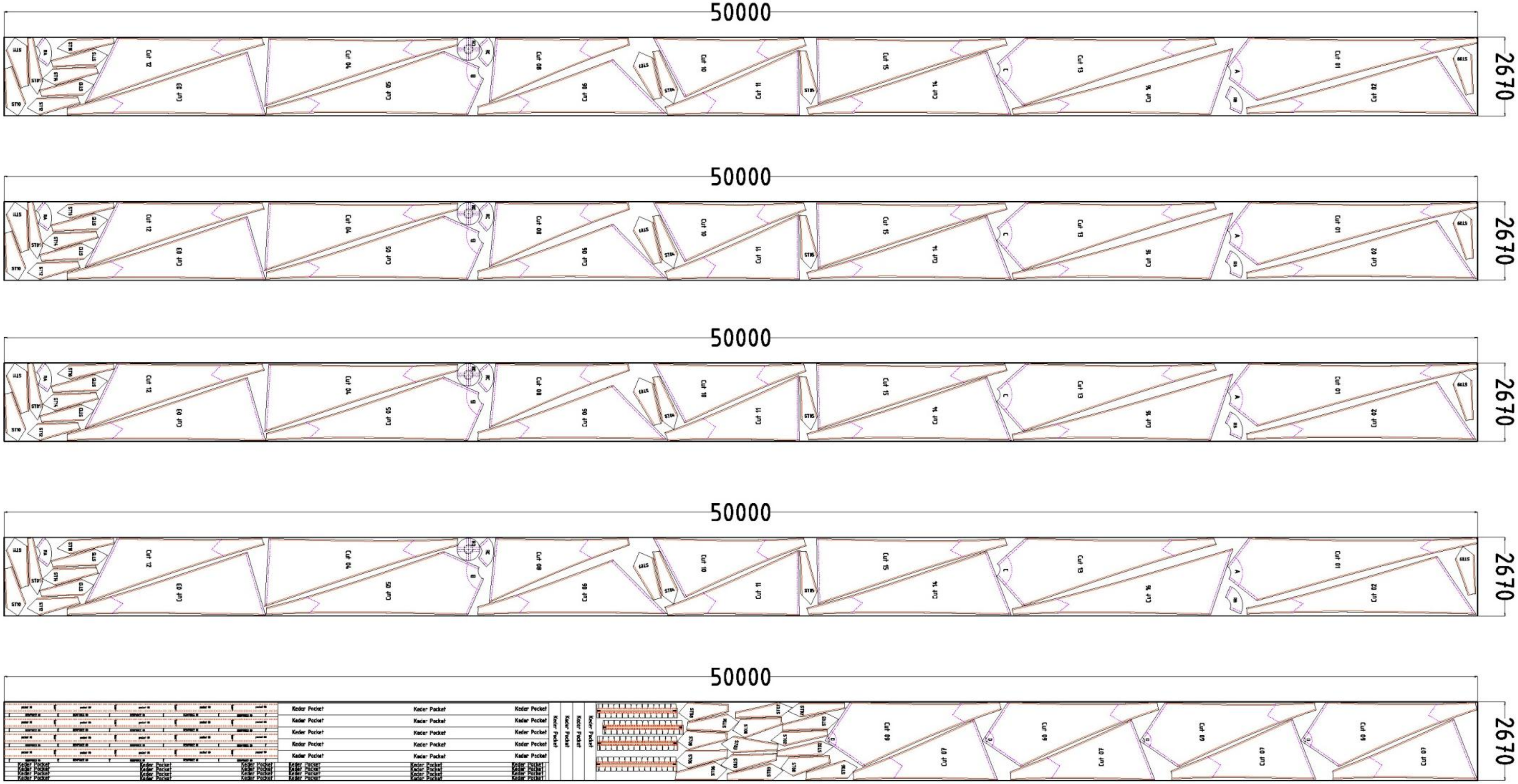
In next step we superimpose plots on fabric rolls and cut the fabric.

Image 104: Plot Assembly

Image 105: Factory, Cutting Fabric

3-8-9 Nesting Panels on The Rolls

Nesting on the rolls are done in a way that the warp directions are correct and along the length of the roll. Pockets and reinforcements are placed on the residual spaces in the correct warp direction, in order to save as much material as possible.



3-9 Membrane Details :

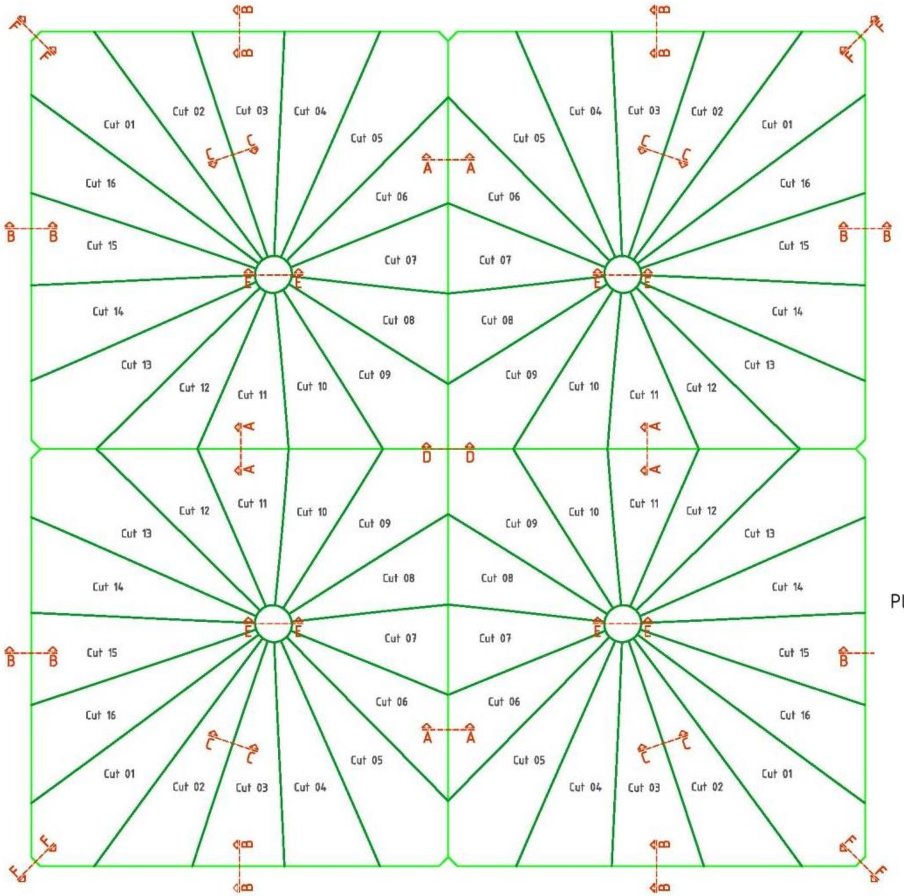
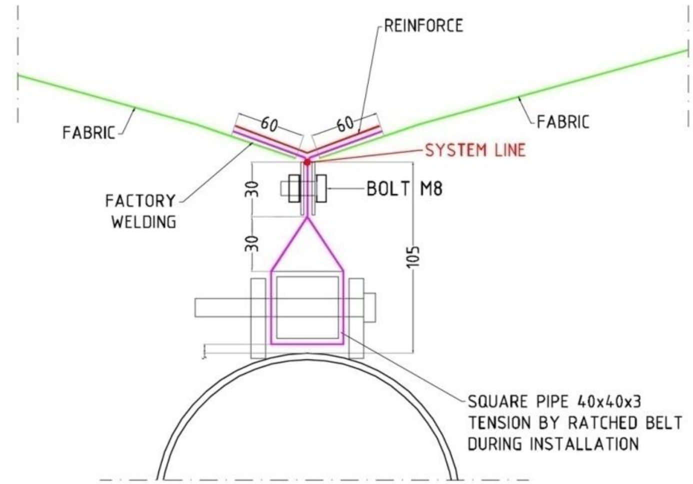
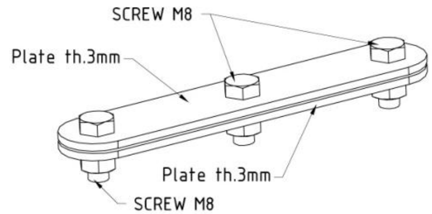
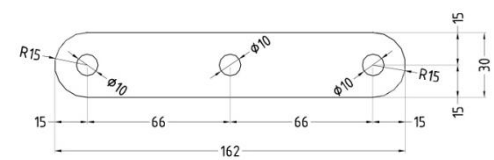


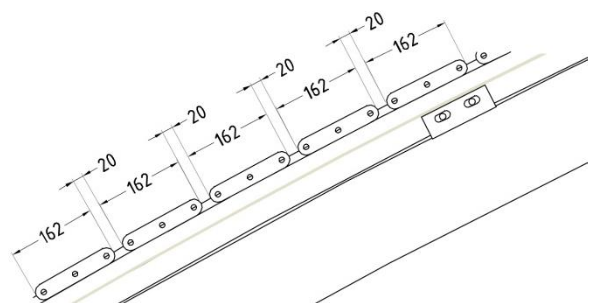
Image 106 : Sections Key Plan

A_A Section



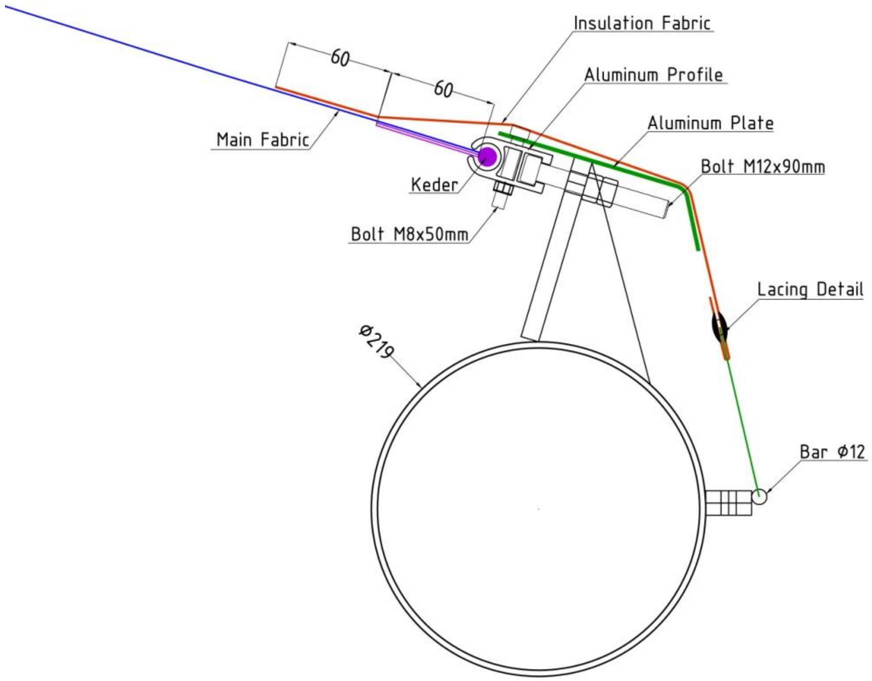


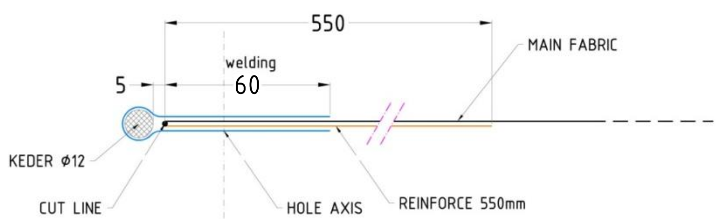




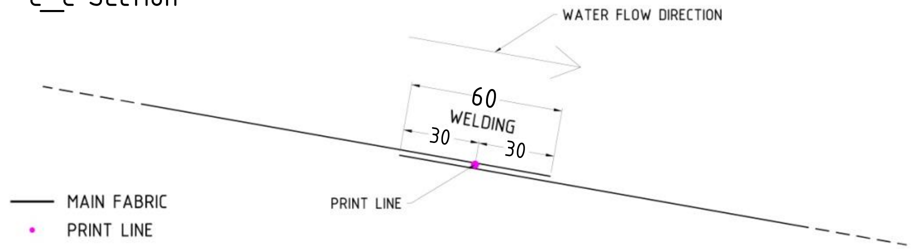
3-9 Membrane Details :

B_B Section

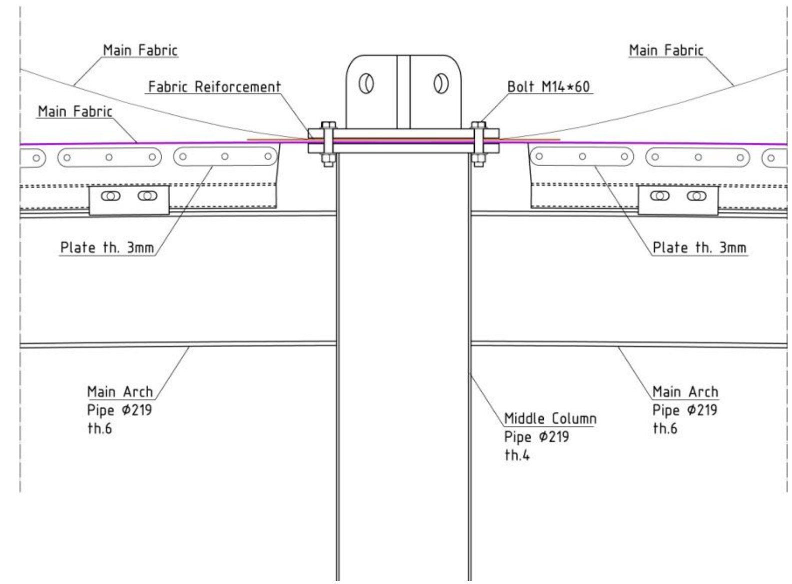




C_C Section

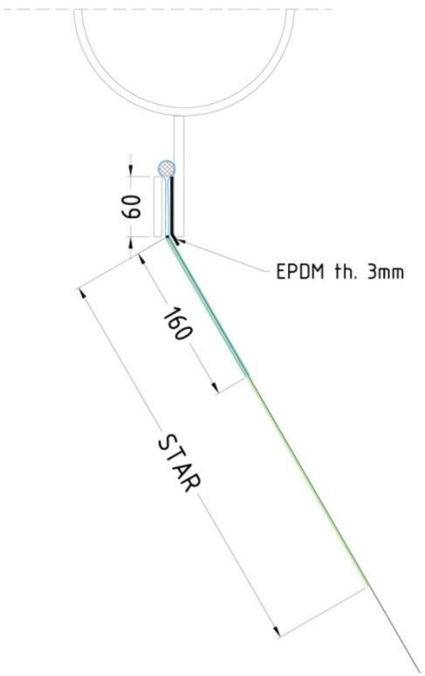


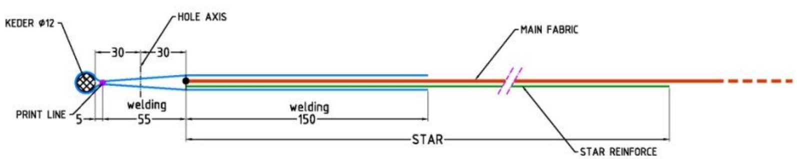
D_D Section



3-9 Membrane Details :

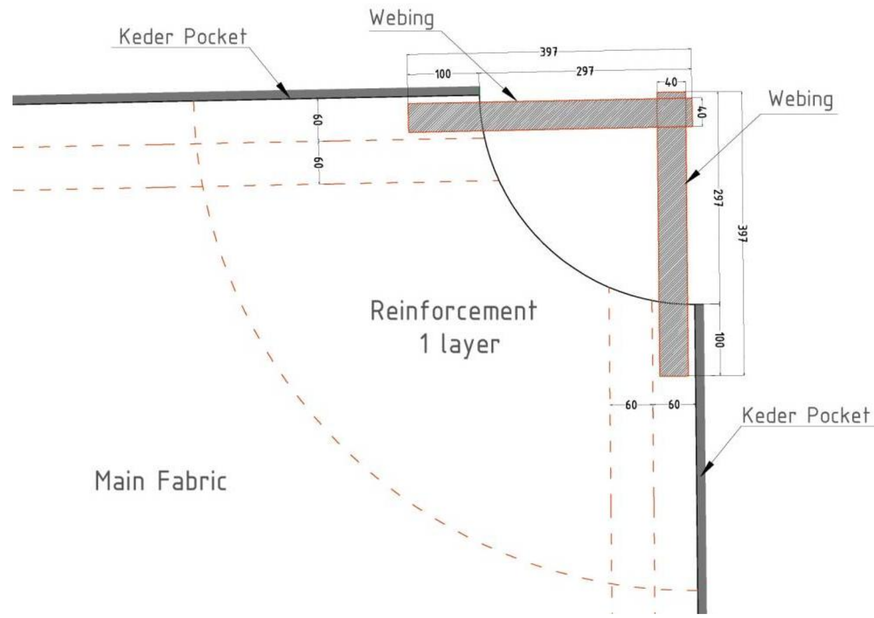
E_E Section

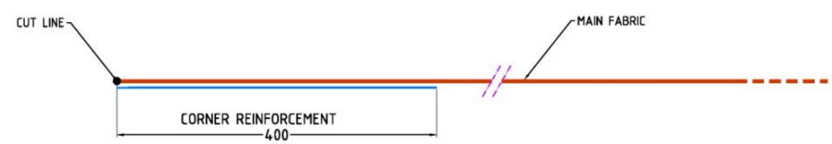




- MAIN FABRIC
- KEDER POCKET
- STAR REINFORCE
- PRINT LINE
- CUT LINE

F_F Section (Corner Detail)





- MAIN FABRIC
- CORNER REINFORCEMENT
- CUT LINE

3-10 Ring Cap Membrane

3D View

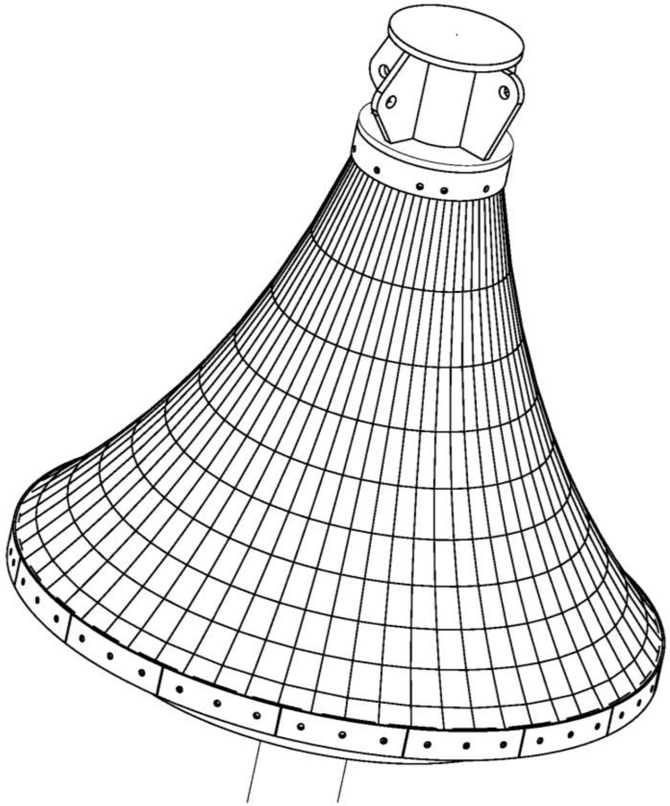
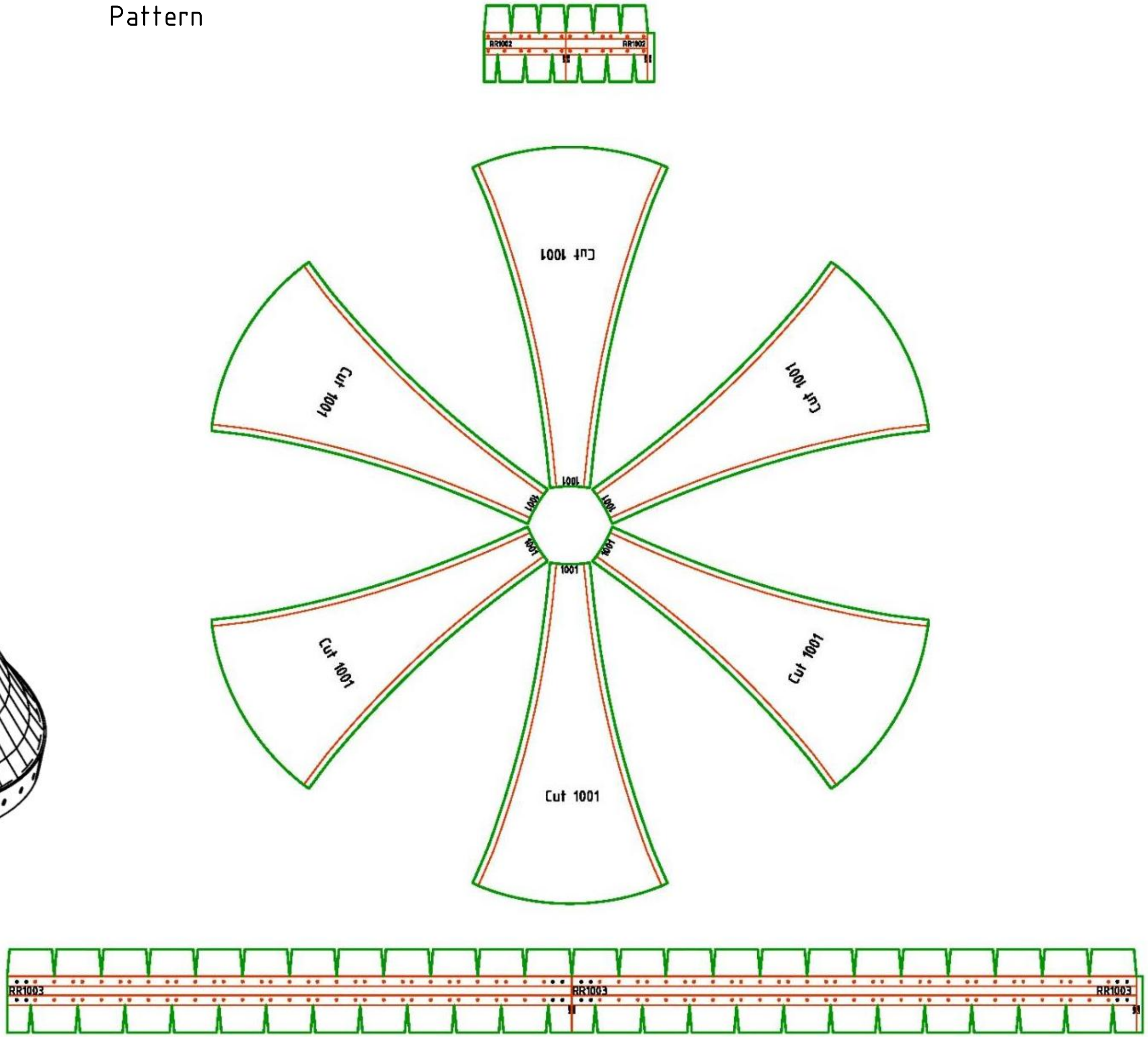


Image 107 : Ring Cap Membrane

Pattern



3-10 Ring Cap Membrane

Details :

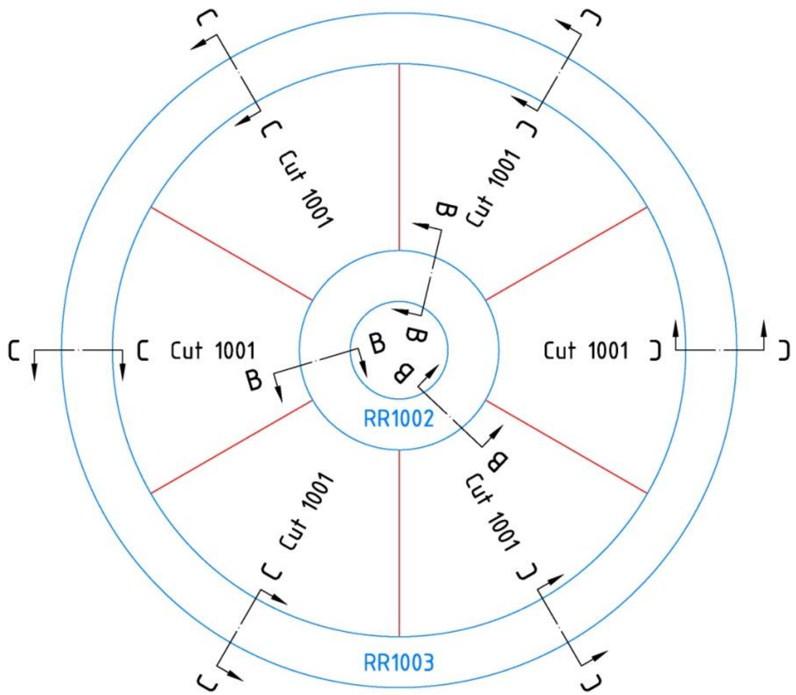
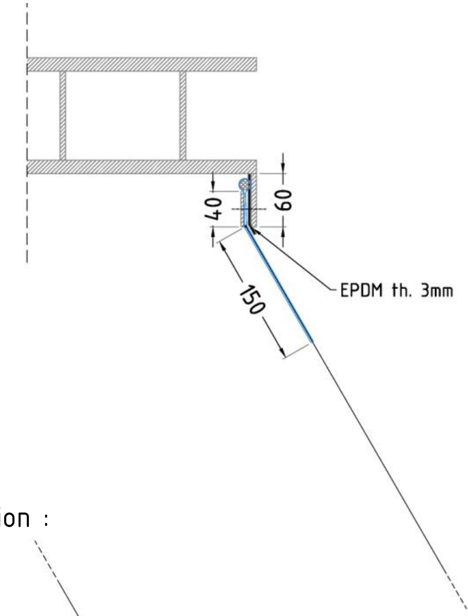
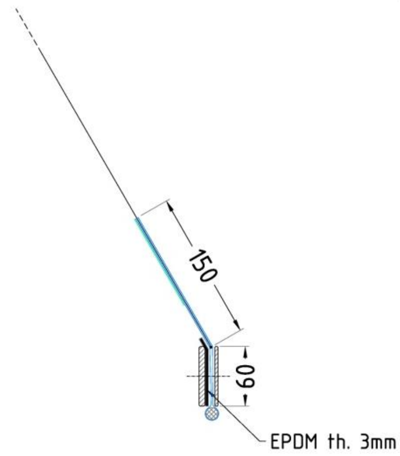


Image 108 : Plan View

B_B Section :



C_C Section :



Chapter 4 :

MANUFACTURING

4-1 plates CNC Cut

After finalizing the design the first step of structure manufacturing is cutting plates, we draw all steel plate in 2D dwg format and arrange them with the exact quantity in steel plates 6x1.5m and send them to plasma workshop , and after receiving the plates we just have to check the quantity , dimensions and holes and then in our workshop we clean them and then we start assembly process.

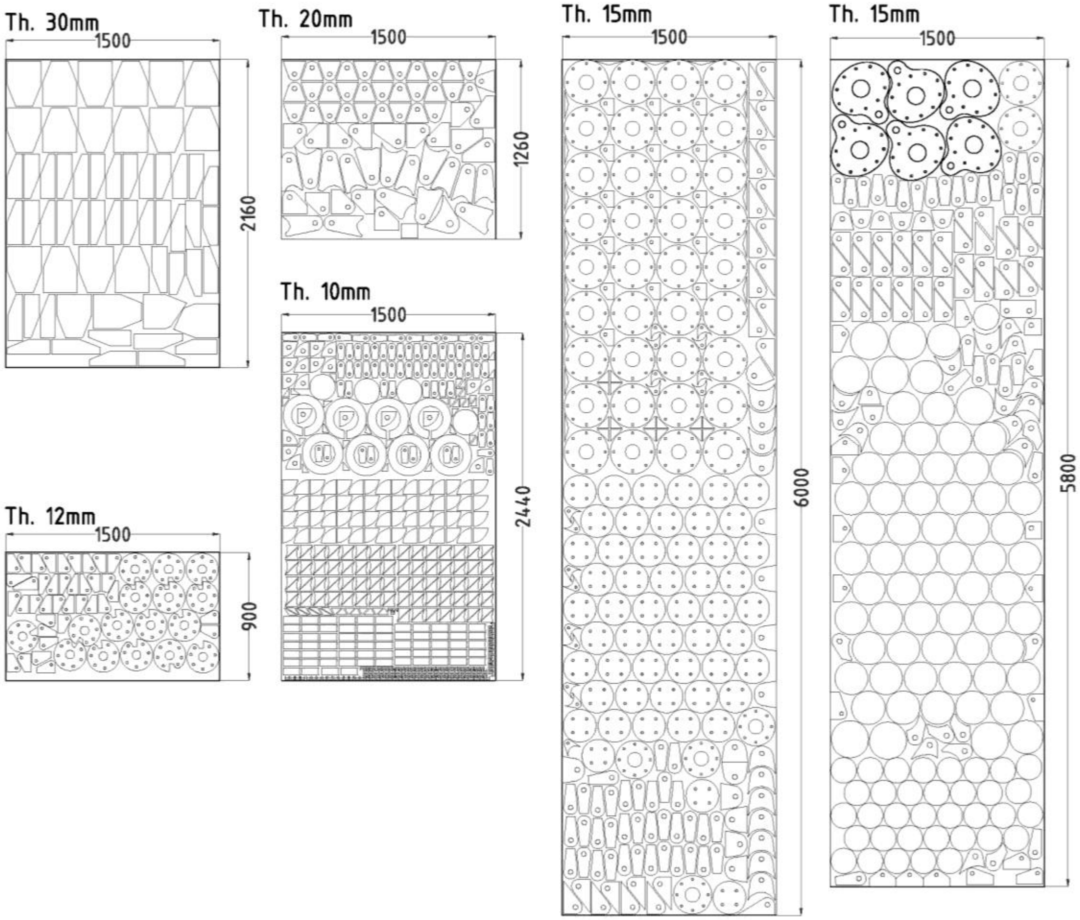
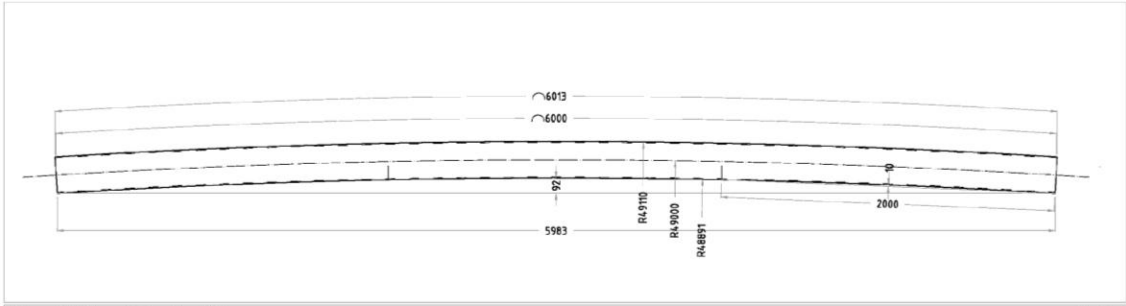


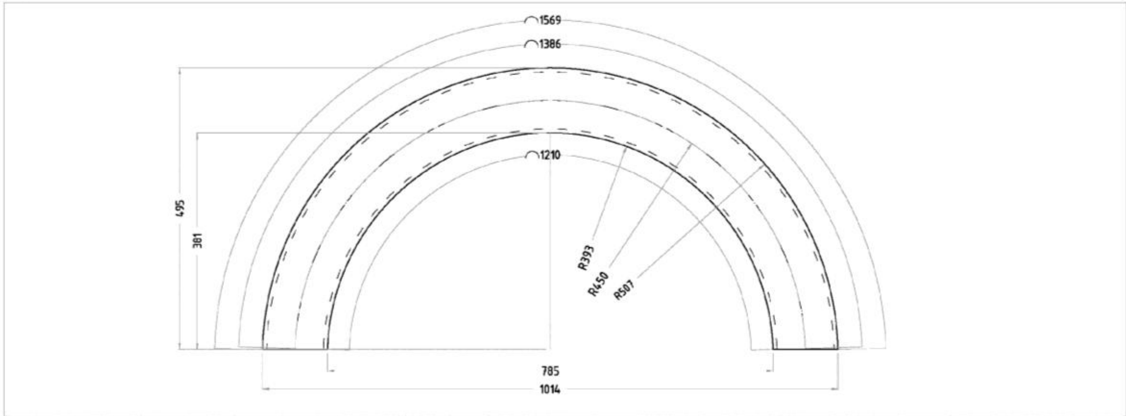
Image 109,110,111 : Plates

4-2 Pipe Rolling :

Before starting the assembly process we send ring and arched beams pipes to pipe rolling workshop, they can roll pipes from 30mm to 323mm diameter and maximum 6m length, so if we need longer elements we should weld rolled pipes to each other to obtain the required length. we have 4 (900mm diameter) rings., so we need to roll pipes with 45cm radius and we also have two arched beams with given radius and length.



Pipe Ø219.1mm (8 inch) th.6 mm N=7



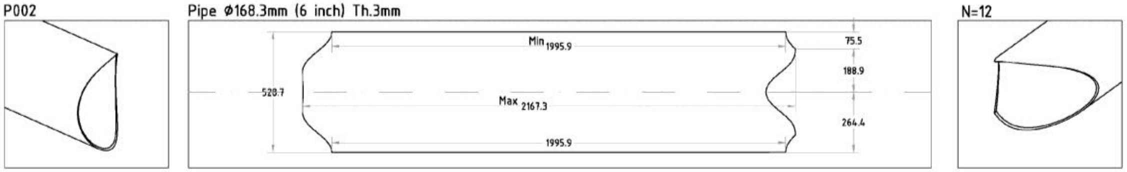
Pipe Ø114mm (4 inch) th.6 mm N=12

Image 112,113,114 : Pipe Rolling

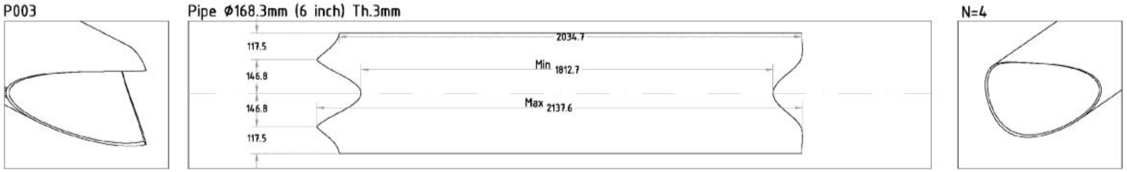
4-3 Pipe Cut :

In our steel workshop first week cut pipes to their approximate length (given length+10-15mm) with saw and then we cut both ends of each element to its specified shape accurately ,in this step we produce a one to one unrolled plot of end shape of each pipe, roll the plot on pipe and draw the cut line on it and then with cut the pipe accurately following that line.

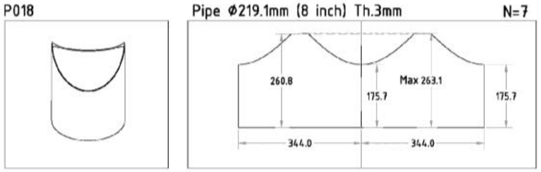
P002 Pipe Ø168.3mm (6 inch) Th.3mm N=12



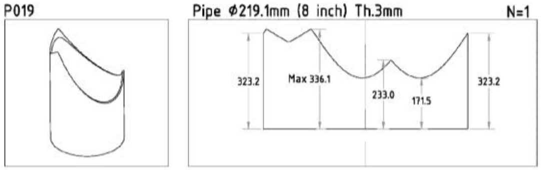
P003 Pipe Ø168.3mm (6 inch) Th.3mm N=4



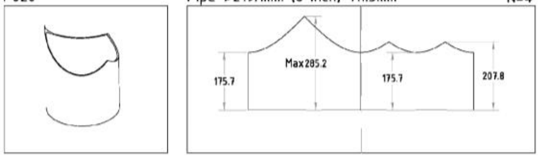
P018 Pipe Ø219.1mm (8 inch) Th.3mm N=7



P019 Pipe Ø219.1mm (8 inch) Th.3mm N=1



P020 Pipe Ø219.1mm (8 inch) Th.3mm N=4



P021 Pipe Ø219.1mm (8 inch) Th.3mm N=2

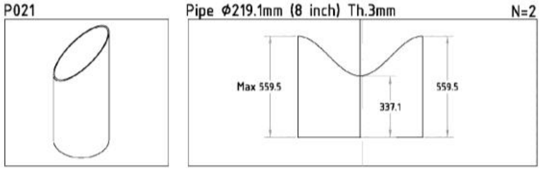


Image 115,116 : Pipe Cut

4-4 Structure Assembling

Trusses

Here below you can see images of trusses manufacturing in our steel workshop, after cutting pipes and plates , we do the primary assembly and then survey team checks the trusses dimensions and signs the plates position on pipes with cameras , after all we fully weld each truss.

Image 117 : Truss Assembly

Image 118 : Ring Assembling

Image 119: Trusses

4-4 Structure Assembling




Image 120,121,122,123 : Structure Assembling

4-5 Structure Painting and Covering

Image 124 : Structure Painting

Image 125 : Truss Painting

Image 126 : Components 07,10

Image 127 : Columns Covering

Image 128 : Component 05

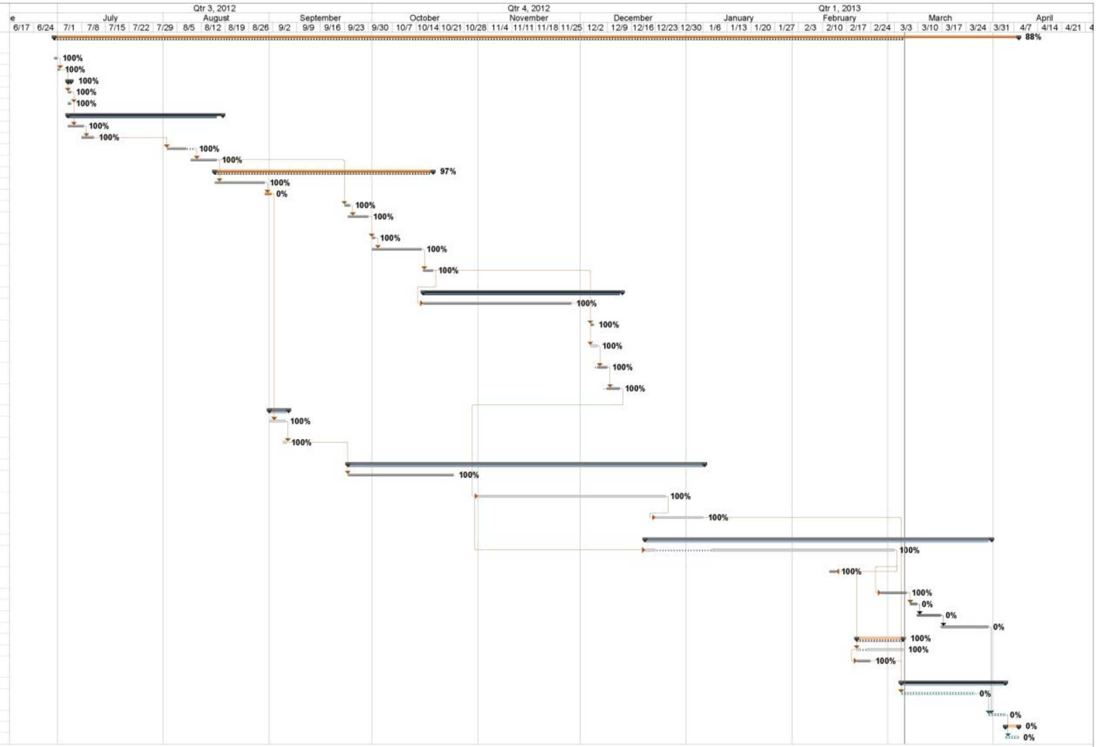
Image 129 : Flymasts Covering

Chapter 5 :

PROJECT MANAGEMENT

5-1 Time Schedule

ID	WBS		Task Name	Duration	Start	Finish
1	**1**		**Membrane Structure For Koohsar Complex**	**231 days**	**Sat 6/30/12**	**Mon 4/8/13**
2	1.1	✓	Feasibility Study	1 day	Sat 6/30/12	Sat 6/30/12
3	1.2	✓	Contract Award	1 day	Sun 7/1/12	Sun 7/1/12
4	**1.3**	✓	**Phase 0**	**1 day**	**Wed 7/4/12**	**Wed 7/4/12**
5	1.3.1	✓	Information gathering	1 day	Wed 7/4/12	Wed 7/4/12
6	1.3.2	✓	Site Visit	1 day	Wed 7/4/12	Wed 7/4/12
7	**1.4**	✓	**Phase 01**	**38 days**	**Wed 7/4/12**	**Sat 8/18/12**
8	1.4.1	✓	Ideation and Preliminary design	3 days	Wed 7/4/12	Sun 7/8/12
9	1.4.2	✓	Evaluation of existing structure- Preliminary 3D model	4 days	Sun 7/8/12	Wed 7/11/12
10	1.4.3	✓	Delivery of first phase Architectural Drawings	5 days	Thu 8/2/12	Thu 8/9/12
11	1.4.4	✓	Confirmation of Architectural Drawings by Clients	7 days	Thu 8/9/12	Thu 8/16/12
12	**1.5**		**Phase 02**	**53 days**	**Thu 8/16/12**	**Thu 10/18/12**
13	1.5.1	✓	Preparation of Node Reaction Report	11 days	Thu 8/16/12	Thu 8/30/12
14	1.5.2		Confirmation of Node Reaction Report by Client	1 day	Thu 8/30/12	Sat 9/1/12
15	1.5.3	✓	Precise surveying of existing structure	2 days	Sun 9/23/12	Mon 9/24/12
16	1.5.4	✓	Foundation and Sub-structure design and preparing the drawings	5 days	Mon 9/24/12	Sat 9/29/12
17	1.5.5	✓	Confirmation of Foundation Drawings	1 day	Mon 10/1/12	Mon 10/1/12
18	1.5.6	✓	Delivery of Foundation Drawings -First Part	13 days	Mon 10/1/12	Mon 10/15/12
19	1.5.7	✓	Delivery of Foundation Drawings -Second Part	3 days	Tue 10/16/12	Thu 10/18/12
20	**1.6**	✓	**Phase 03**	**48 days**	**Tue 10/16/12**	**Thu 12/13/12**
21	1.6.1	✓	Execution of Foundation and Sub-structure by Client	35 days	Tue 10/16/12	Wed 11/28/12
22	1.6.2	✓	Inspection of Foundation and Sub-structure Execution by Diba	1 day	Tue 12/4/12	Tue 12/4/12
23	1.6.3	✓	Precise surveying of exeuted Foundation and Sub-structure	2 days	Tue 12/4/12	Wed 12/5/12
24	1.6.4	✓	Evaluation of necessary changes to the 3D model	2 days	Wed 12/5/12	Sat 12/8/12
25	1.6.5	✓	3D model revision and applying necessary changes	4 days	Sat 12/8/12	Wed 12/12/12
26	**1.7**	✓	**Phase 04**	**6 days**	**Sat 9/1/12**	**Thu 9/6/12**
27	1.7.1	✓	Preparation of Phase 1 drawings for the structure	5 days	Sat 9/1/12	Wed 9/5/12
28	1.7.2	✓	Confirmation of Phase 1 drawings for the structure by Client	1 day	Wed 9/5/12	Wed 9/5/12
29	**1.8**	✓	**Phase 05**	**87 days**	**Mon 9/24/12**	**Sun 1/6/13**
30	1.8.1	✓	Preparation of Precise 3D model- Fabric & Structure	27.5 days	Mon 9/24/12	Wed 10/24/12
31	1.8.2	✓	Preparation of Shop Drawings for Main Structure	44.88 days	Thu 11/1/12	Tue 12/25/12
32	1.8.3	✓	Preparation of Shop Drawings for the Fly- Mast	11.25 days	Sun 12/23/12	Sat 1/5/13
33	**1.9**		**Phase 06**	**79 days**	**Thu 12/20/12**	**Sun 3/31/13**
34	1.9.1	✓	Manufacturing of the Main Structure and Connections	45 days	Thu 12/20/12	Sat 3/2/13
35	1.9.2	✓	Preparation of As Built drawings for the Manufactured Structure	2 days	Tue 2/12/13	Wed 2/13/13
36	1.9.3	✓	Painting the Structure- Primer Paint	7 days	Wed 2/27/13	Wed 3/6/13
37	1.9.4		Transportation of the Structure	1 day	Thu 3/7/13	Sat 3/9/13
38	1.9.5		Installation of the Structure	6 days	Sat 3/9/13	Sat 3/16/13
39	1.9.6		Painting the Structure	7 days	Sat 3/16/13	Sat 3/30/13
40	**1.10**	✓	**Phase 07**	**12 days**	**Wed 2/20/13**	**Tue 3/5/13**
41	1.10.1	✓	Fabric Patterning	11 days	Wed 2/20/13	Tue 3/5/13
42	1.10.2	✓	Preparation of Fabric Connection Drawings	3 days	Wed 2/20/13	Sat 2/23/13
43	**1.11**		**Phase 08**	**22 days**	**Tue 3/5/13**	**Thu 4/4/13**
44	1.11.1		Manufacturing of the Fabric and the Connections	14 days	Tue 3/5/13	Tue 3/26/13
45	1.11.2		Installation of Fabric and Connections	5 days	Sat 3/30/13	Thu 4/4/13
46	**1.12**		**Phase 09**	**3 days**	**Thu 4/4/13**	**Mon 4/8/13**
47	1.12.1		Project Handout	3 days	Thu 4/4/13	Mon 4/8/13



Page 1

5-1 Time Schedule

ID	WBS	Info	Task Name	Duration	Start	Finish
1	**1**		**Membrane Structure For Koohsar Complex**	**231 days**	**Sat 6/30/12**	**Mon 4/8/13**
2	1.1	✓	Feasibility Study	1 day	Sat 6/30/12	Sat 6/30/12
3	1.2	✓	Contract Award	1 day	Sun 7/1/12	Sun 7/1/12
4	**1.3**	✓	**Phase 0**	**1 day**	**Wed 7/4/12**	**Wed 7/4/12**
5	1.3.1	✓	Information gathering	1 day	Wed 7/4/12	Wed 7/4/12
6	1.3.2	✓	Site Visit	1 day	Wed 7/4/12	Wed 7/4/12
7	**1.4**	✓	**Phase 01**	**38 days**	**Wed 7/4/12**	**Sat 8/18/12**
8	1.4.1	✓	Ideation and Preliminary design	3 days	Wed 7/4/12	Sun 7/8/12
9	1.4.2	✓	Evaluation of existing structure- Preliminary 3D model	4 days	Sun 7/8/12	Wed 7/11/12
10	1.4.3	✓	Delivery of first phase Architectural Drawings	5 days	Thu 8/2/12	Thu 8/9/12
11	1.4.4	✓	Confirmation of Architectural Drawings by Clients	7 days	Thu 8/9/12	Thu 8/16/12
12	**1.5**		**Phase 02**	**53 days**	**Thu 8/16/12**	**Thu 10/18/12**
13	1.5.1	✓	Preparation of Node Reaction Report	11 days	Thu 8/16/12	Thu 8/30/12
14	1.5.2		Confirmation of Node Reaction Report by Client	1 day	Thu 8/30/12	Sat 9/1/12
15	1.5.3	✓	Precise surveying of existing structure	2 days	Sun 9/23/12	Mon 9/24/12
16	1.5.4	✓	Foundation and Sub-structure design and preparing the drawings	5 days	Mon 9/24/12	Sat 9/29/12
17	1.5.5	✓	Confirmation of Foundation Drawings	1 day	Mon 10/1/12	Mon 10/1/12
18	1.5.6	✓	Delivery of Foundation Drawings -First Part	13 days	Mon 10/1/12	Mon 10/15/12
19	1.5.7	✓	Delivery of Foundation Drawings -Second Part	3 days	Tue 10/16/12	Thu 10/18/12
20	**1.6**	✓	**Phase 03**	**48 days**	**Tue 10/16/12**	**Thu 12/13/12**
21	1.6.1	✓	Execution of Foundation and Sub-structure by Client	35 days	Tue 10/16/12	Wed 11/28/12
22	1.6.2	✓	Inspection of Foundation and Sub-structure Execution by Diba	1 day	Tue 12/4/12	Tue 12/4/12
23	1.6.3	✓	Precise surveying of exeuted Foundation and Sub-structure	2 days	Tue 12/4/12	Wed 12/5/12

5-1 Time Schedule

ID	WBS		Task Name	Duration	Start	Finish
24	1.6.4	✓	Evaluation of necessary changes to the 3D model	2 days	Wed 12/5/12	Sat 12/8/12
25	1.6.5	✓	3D model revision and applying necessary changes	4 days	Sat 12/8/12	Wed 12/12/12
26	**1.7**	✓	**Phase 04**	**6 days**	**Sat 9/1/12**	**Thu 9/6/12**
27	1.7.1	✓	Preparation of Phase 1 drawings for the structure	5 days	Sat 9/1/12	Wed 9/5/12
28	1.7.2	✓	Confirmation of Phase 1 drawings for the structure by Client	1 day	Wed 9/5/12	Wed 9/5/12
29	**1.8**	✓	**Phase 05**	**87 days**	**Mon 9/24/12**	**Sun 1/6/13**
30	1.8.1	✓	Preparation of Precise 3D model- Fabric & Structure	27.5 days	Mon 9/24/12	Wed 10/24/12
31	1.8.2	✓	Preparation of Shop Drawings for Main Structure	44.88 days	Thu 11/1/12	Tue 12/25/12
32	1.8.3	✓	Preparation of Shop Drawings for the Fly- Mast	11.25 days	Sun 12/23/12	Sat 1/5/13
33	**1.9**		**Phase 06**	**79 days**	**Thu 12/20/12**	**Sun 3/31/13**
34	1.9.1	✓	Manufacturing of the Main Structure and Connections	45 days	Thu 12/20/12	Sat 3/2/13
35	1.9.2	✓	Preparation of As Built drawings for the Manufactured Structure	2 days	Tue 2/12/13	Wed 2/13/13
36	1.9.3	✓	Painting the Structure- Primer Paint	7 days	Wed 2/27/13	Wed 3/6/13
37	1.9.4		Transportation of the Structure	1 day	Thu 3/7/13	Sat 3/9/13
38	1.9.5		Installation of the Structure	6 days	Sat 3/9/13	Sat 3/16/13
39	1.9.6		Painting the Structure	7 days	Sat 3/16/13	Sat 3/30/13
40	**1.10**	✓	**Phase 07**	**12 days**	**Wed 2/20/13**	**Tue 3/5/13**
41	1.10.1	✓	Fabric Patterning	11 days	Wed 2/20/13	Tue 3/5/13
42	1.10.2	✓	Preparation of Fabric Connection Drawings	3 days	Wed 2/20/13	Sat 2/23/13
43	**1.11**		**Phase 08**	**22 days**	**Tue 3/5/13**	**Thu 4/4/13**
44	1.11.1		Manufacturing of the Fabric and the Connections	14 days	Tue 3/5/13	Tue 3/26/13
45	1.11.2		Installation of Fabric and Connections	5 days	Sat 3/30/13	Thu 4/4/13
46	**1.12**		**Phase 09**	**3 days**	**Thu 4/4/13**	**Mon 4/8/13**
47	1.12.1		Project Handout	3 days	Thu 4/4/13	Mon 4/8/13

❋ 5-2 Cost Estimate

Cost Estimate

		Subject	Quantity	Unit	Price/Unit	Price	Total Price
DESIGN	Design	Architectural Design				€ 3,000.00	€ 10,000.00
		Engineering				€ 7,000.00	
		Shop Drawing					
SUPPLY	Structure	Steel pipes and plates(material)	10000	Kg	€ 1.00	€ 10,000.00	€ 32,300.00
		Production(Cutting+Assembly)	10000	Kg	€ 1.90	€ 19,000.00	
		Painting/Galvanization	10000	Kg	€ 0.33	€ 3,300.00	
	Connections	Steel Connections	80	No.	€ 10.00	€ 1,503.12	€ 5,223.12
		PINS And Bolts	2068	No.	€ 0.34		
		Aluminium profile	80	m	€ 4.00	€ 320.00	
		Rod	34	No.	€ 100.00	€ 3,400.00	
	Cables	Cable	120	m	€ 7.00	€ 840.00	€ 1,000.00
		Swaging/Pressing	16	No.	€ 10.00	€ 160.00	
	Fabric	Fabric	735	m²	€ 19.00	€ 13,965.00	€ 20,665.00
		Fabrication	670	m²	€ 10.00	€ 6,700.00	
Installation	Transportation	Structure	3	Truck	€ 250.00	€ 750.00	€ 750.00
		Fabric					
		Cable					
	Crane	Crane	48	Hour	€ 14.00	€ 672.00	€ 672.00
	Installation	Structure	400	m²	€ 3.25	€ 1,300.00	€ 1,300.00
		Fabric		m²			
ADDITIONAL SERVICES	Test	Fabric		Fix		€ 0.00	€ 200.00
		Cables & Connections		Fix		€ 200.00	
	Maintenance	Fabric	1	Year	€ 3,000.00	€ 3,000.00	€ 3,000.00
		Structure					
						Total	**€ 75,110.12**

References

1. Wikipedia-Free encyclopedia-Nomadic Tents and Bakhtiari People
2. Wikipedia-Free encyclopedia- Persian Architecture
3. Dr. Ing. Massimo Maffeis Structural Report Documents
4. European Design Guide for Tensile surface structures
5. IRANIAN CODE NO. 6 : Loads on structures (Wind & Snow)
6. Membrane Construction, Connection Details, Bubner, Ewald, Edition 1997,1999
7. Construction Manual for Polymers+ Membranes, Knippers , Cremers , Gabler , Lienhard , Edition Detail 2011
8. Membrane Structures (Innovative Building with Film and Fabric, Edited by Klaus-Michael Koch, With Karl J. Haberman, 2004