THE DESIGN OF VISITOR’S SHED IN DHAKA ZOO: “GOLDEN FIBER” JUTE AS TENSILE MEMBRANE

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

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Statement

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

The Design of Visitor’s shed In Dhaka Zoo: “Golden Fiber” Jute as Tensile Membrane,

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

Dhaka, Bangladesh, 24-2-2013 Golam Morsalin Choudhury Rana

Acknowledgement

I would like to thank all the people who helped me in preparation of this thesis work. First of all I would like to mention Prof. Dr. Robert Off for his continuous support throughout the course. I would like to thank him for his dedication and passion in handling entire course work at Institute for Membrane and Shell Technologies, IMS e.V.

I would like to my gratitude to Atisit Sabmeethavorn for his guidance and support throughout the thesis work. I will always remember his dedication and kind behavior through the course.

I would like to express my special thanks to Prof. Dr. Shabbir Ahmed, Department of Architecture, Bangladesh University of Engineering and Technology, BUET for his inspiration, encouragement and support throughout the course.

I would like to thank following individual:

Md. Moslem Uddin from Textile Physics Division of Bangladesh Jute Research Institute, BJRI for his continuous untiring support and guidance on my thesis work.

Prof. Dr. Abdul Jabbar Khan, Department of Civil Engineering, Bangladesh University of Engineering and Technology, BUET for his guidance on material testing.

Heike Kleine, Assistant IMS e. V. for her support, patience and providing license key whenever author needed.

Architect Amandus VanQuaille, Nomad Concept Belgium for his technical support.

Finally this thesis is whole heartedly dedicated to my parents for their relentless support, love and affection.

Golam Morsalin Choudhury Rana
Dhaka, 24 February 2013

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Abstract

This paper explores the opportunity of using Jute fabric as an alternative material for tensile membrane structures. Jute has many environmental benefits. It is biodegradable, nontoxic and has high tensile strength. Application of Jute based product is green, sustainable and reduces carbon footprint.

Jute cord, ropes, bags are being used for centuries, and Bangladesh is the natural home of the best quality Jute. Bangladesh is the largest Jute exporter in the world. Wide range of products is made from Jute. Technical textiles such as Jute geotextiles (JGT) made from Jute are being used in road construction, river bank erosion control, filtration etc. Many researches are being undertaken to improve the quality and longevity of Jute. One study indicates that chemically treated Jute fabric can last upto 20yrs.

Tensile fabric structures are special type of structures where roofs or canopies were loaded only in tension. Tensile fabric structures are lightweight, translucent, flexible, and have sculptural quality comparing to traditional structures. These qualities tensile membrane structures match the requirements of visitor's shed design in Dhaka zoo.

Since Jute is an indigenous material, locally available, low cost, ecofriendly and has good tensile strength, so Jute fabric is selected to be used as an experimental tensile fabric material for the proposed shed structure in Dhaka Zoo. The combination of Jute fabric and support structure will add sculptural quality and lightweightedness in zoo environment. This study will open up possibilities of Jute fabric to become an alternative for tensile fabric structures.

Chapter 01:

Introduction

1.1 Introduction

Tensile membrane structures are very lightweight and require minimum supporting structures to be built[1]. Sculptural forms & shapes of them attract people. They can be temporary & mobile and require less hard surfaces. These advantages are suitable for a visitor shade. So, tensile membrane structure is selected to design a visitor shade in Dhaka Zoo.

Prestressed membrane is used for structural stability in tensile membrane structures. The materials used for membranes are generally consisting of artificial woven fabric coated with polymeric resin[2]. Natural fabric such as fabric made of Jute fiber has huge potential to become an alternative membrane material. As Jute fiber has good tensile strength. Jute ropes and bags are widely used to carry loads. Jute has many ecological benefits. It is environment friendly, nontoxic and biodegradable. Recent study shows that treated Jute fabric can last upto 20yrs[3].

Selecting natural fiber based products rather than synthetic fibers can reduce CO_2 emission. Thereby reducing greenhouse effect caused by CO_2. Increasing awareness in this issue leads to more in depth research on natural resources. The industrial and natural life cycles of a product made from renewable resources shown in Fig. 01. CO_2 produced by incineration at the end of technical cycle is compensated through photosynthesis during growth making total CO_2 balance is zero[4].

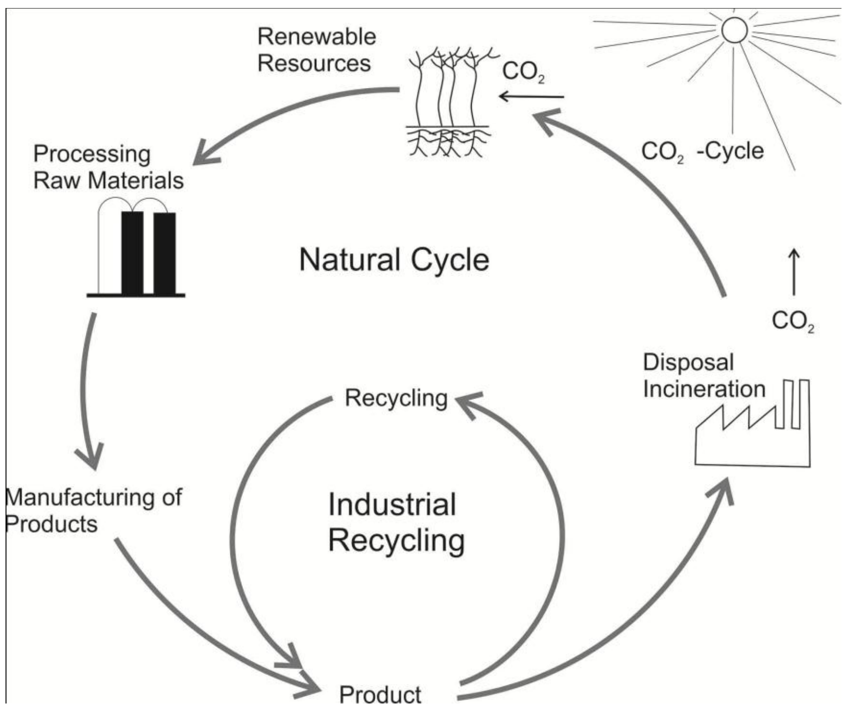

Figure 1: Interaction between natural and industrial cycles. (Reported by Loan, 2006)

Jute is an indigenous material of Bangladesh. Bangladesh is the natural home of best Jute in the world. Jute is readily available and cheap. Bangladesh is the largest exporter of raw Jute in the world[5]. Jute is related with development of economy and poor rural communities in Bangladesh. Govt. of Bangladesh is encouraging diversified uses of Jute. Technical textiles produced from Jute fabric such as Jute Geotextiles (JGT) are one of the diversified uses of Jute, which are now used in road construction, preventing soil erosion, filtration etc[6].

1.2 Objectives

This paper investigates the potential of Jute fabric to be used as tensile membrane for visitor shade at Dhaka Zoo. It will enhance the applicability of Jute fabric and lead the way to future in depth study on Jute fabric as a membrane material.

1.3 Scope and Limitations

This study is mainly focused on Jute fabric available in local market. Among them one side laminated hessian type Jute fabric and Jute-cotton 50:50 union fabric tested in BUET lab. Double side coated fabric is not available but it can be produced in factory only for large quantities.

Testing of the Jute fabrics have been done in the labs of Bangladesh University Engineering &Technology (BUET) and Bangladesh Jute Research Institute (BJRI).

Jute fabrics which are selected in this study are not UV protected and weldable. Researches are going on to make Jute fabric UV protected. There are possibilities to make it weldable, but it is out of the scope of this study.

1.4 Approach

The approach to design a visitor shed using Jute fabric will be divided into two phases. In study phase a suitable Jute fabric will be selected based on literature review and market survey. Then in design phase after loadcase analysis, strength of the fabric will be checked if its strength is above the required safety level than the fabric will be selected for detail design.

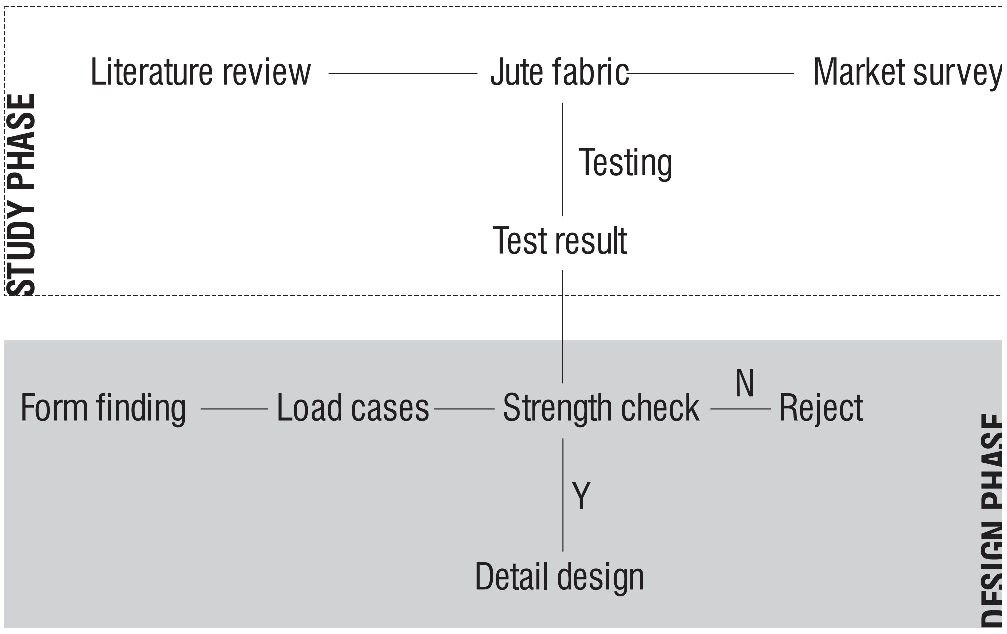

Figure 2: Structure of the work

1.5 Thesis Structure

After introduction in chapter01, background of the thesis work will be discussed in chapter 02. A short overview on tensile membrane structures and a short history of fabric structures in Bangladesh will be discussed. And then project description and site location will be presented.

In chapter 03 Jute, properties of Jute yarn, Jute geotextiles, Jute cotton union fabrics will be studied thoroughly and a fabric will be selected based on tensile strength for design phase.

Then in chapter 04 design will be developed and form finding will be done. Membrane will be analyzed for different load cased. Then strength of the fabric will be evaluated. If it is ok then detail design will be done.

The fabrication process will be discussed in chapter 05. Cost estimation, time schedule will be presented. A guideline for erection procedure will be given.

Conclusive remarks and evaluation of the findings will be discussed in chapter 06

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1. Brian Forster, Marijke Mollaert; Engineering Fabric Architecture, European Design Guide for Tensile Surface Structures, Tensinet, 2004.
2. Rainer Blum, Heidrun Bogner, Guy Nemoz; Material Properties and Testing, European Design Guide for Tensile Surface Structures, Tensinet, 2004.
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6. Dr. A. B. Jabbar Khan, Technical Assessment of Jute Geotextiles for Civil Engineering Applications, Department of Civil Engineering, Bangladesh University of Engineering & Technology (BUET), Dhaka, Bangladesh, June 2008

Chapter 02:

Tensile membrane structures and history of fabric structures in Bangladesh

2.1 Tensile Membrane Structures

Tensile membrane structures are generally composed of lightweight membrane or fabric and primary structure, where membrane is loaded only in tension supported by primary structure. Tensile membrane structures are lightweight, flexible and more stable than conventional structures[1]. Modern tensile fabric structures have relation and similarities with traditional and nomadic tents. The materials of old nomadic tents were hand woven wool with wooden stakes as primary structure. But the modern tensile membrane structure uses steel masts, arches, semi-grid support as primary structure and membrane with associated cables as secondary structures[2].

The art of modern lightweight membrane structure started from 1950's. 'Minimal surface' concept of modern membrane structures are based on Frei Otto's soap film experiments. Minimal surface requires least amount of potential energy within a set of boundary. With minimally shaped surfaces varieties of sculptural shapes and spaces can be produced. They can be translucent and provide shade from sun, rain, wind. So with minimally shaped surfaces more can be achieved with less, in other words- less is more[3].

2.1.1 Qualities of Membrane Structures

Tensile membrane structures have some advantages over traditional structures. The major advantage of tensile membrane structures is its lightweightness. Prestessed shapes of the membrane, low mass and wide span provide opportunity to express lightness and stability[3].

Figure 3: Fountain Tent Starwave, Cologne, Germany, rebuilt 2000, Architekturbüro Rasch + Bradatsch with Frei Otto.

Translucency is one of the great qualities of tensile membrane structures. It offers aesthetic opportunity to design with natural and artificial light. Translucency depends on the type, coating and color of membrane material. Translucency can vary from 10% to 40%[3].

Figure 4: Assembly Tent, Malaysia, 1997, SL Rasch

Tensile membrane structures are not rigid. Membrane shape deforms in response to snow and wind load. It finds efficient shape for different loading conditions which offers better flexibility. Unique sculptural shapes can be achieved through membrane structures. It offers a floating quality defying gravity. With the help of artificial lighting it offers an opportunity to design a tensile membrane structure into a sculpture of light[3].

Figure 5: Julianus Shopping Mall, Tongeren, Belgium, 2007, The Nomad Concept

Membrane material with open structure can be used for shading and stimulate natural ventilation. The open air feeling and impression of lightness of tensile membrane structures are reinforced by the translucency of membrane material[3].

Figure 6: Fort 4 Mortsel, Antwerp, Belgium, 2002, The Nomad Concept

Tensile membrane structures can be the synthesis of nomad tent and permanent settlement. Flexibility and lightness of materials make them to be built again and again in different places. They can be erected again and again at different places. For these mobility and flexibility tensile membrane structures can be used in case of emergency situations and also they can be served for various open public events, which in turn save urban open spaces.

1.2 History of Fabric Structures in Bangladesh

Bangladesh has a long tradition of fabric structures, which has been influenced by many traditions and cultures in this region. Traditional fabric structures like Pandal and Shamiana are being erected throughout the history as temporary shelters for different festivals and ceremonies. Pandals are generally erected as temporary shed for different religious festivals & weddings especially by Hindus and Buddhist from ancient times. Hindu community in Bangladesh set up large puja pandals during *Durga Puja* to venerate the goddess Durga[4]. Traditional ceremonial tent Shamiana was introduced by Mughal regime in India[5]. Shamiana was richly decorated fabric hanged in Mughal and Rajput courts. It's a temporary structure erected on different royal or public events.

Figure 7: Mughal Shamiana in front of Divan-i Khass in the Palace of the Delhi Fort, water color by Ghulam Ali Khan, 1817

Figure 8: Durga puja pandal, author Mukerjee, October 2008

Figure 9: A Pandel gateway in Dhaka.(Author Pro. Dr. Shabbir Ahmed, 2011)

Figure 10: 10th convocation pandel of Bangladesh University of Engineering & Technology (BUET), 3rd February 2011

Shamiana or pandals are still being erected during various religious festivals, public events, parties, marriage ceremonies etc. One of the biggest examples is '*Bisho Ijtema'*. Largest tent structure using jute fabric is erected over an area of 160 acres[7]. '*Bisho Ijtema'* is an Islamic religious congregation held on the bank of river Turag in Tongi, Gazipur each year. Porous hessian Jute fabric is used as fabric material to shade the area.

Figure 11: BishoIjtema on the bank of river Turag, Tongi, Gazipur.(source: www.thedailystar.net)

Figure 12: Inside view of *Bisho Ijtema* tent. (Author Rocky S. Hossain, 2010)

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2. Erik Moncrieff, Brian Forster; Glossary, European Design Guide for Tensile Surface Structures, Tensinet, 2004.
3. Jurgen Bradatsch, Peter Patzold, Cristiana Saboia de Freitas, Rudi Scheuermann, Juan Monjo, Marijke Mollaert; Form, European Design Guide for Tensile Surface Structures, Tensinet, 2004.
4. Rabindranath Trivedi, The Durga puja and Minority Rights of Bangladesh, Asian Tribune, 19 October 2012.
5. Shireen Akbar, Shamiana: The Mughal Tent, Victoria & Albert Museum, January 1999
6. The Divan-i Khass in the Palace in the Delhi Fort, http://www.bl.uk/onlinegallery/onlineex/apac/addorimss/t/019addor0004694u00000000.html Accessed on 13-11-12
7. All set for Biswa Ijtema from Saturday, The Daily Star, 22 December, 2003

Chapter 03:

Jute

3.1 Introduction of Jute

Jute is a natural plant. Jute fiber is collected from the bark of the plant and is yellowish golden in color. Jute is called the golden fiber of Bangladesh. Bangladesh is the natural home of best quality Jute. Jute is related with development of economy and poor rural communities in Bangladesh. Jute genome sequencing is decoded by a team of Bangladeshi scientists which opens up huge potentials for Jute development[1].

Figure 13: Jute plant. **Figure 14: Jute collection from field.**
(source left image http://www.thejutecompany.com/images/juteplant.jpg)
(source right image http://media.lonelyplanet.com/lpi/2994/2994-27/681x454.jpg)

Bangladesh is the largest exporter of raw Jute in the world[2]. But export growth of Jute and Jute items has sharply deceased from 1970's[3]. There was a negative growth rate in 80's. The Govt. of Bangladesh has taken initiative to curb the export growth rate of Jute and Jute. For that purpose diversified use of Jute have been motivated and given incentives.

Table 1: Growth Performance of Jute and Jute Goods Export by Bangladesh (reported in Mustafizur Rahman, Nafisa Khaled, 2011)

Item	FY1973 – FY1981	FY1981 – FY1991	FY1991 – FY2001	FY2001 – FY2010	FY1973 – FY2010
Raw jute	1.0	-1.2	-1.2	13.3	-0.4
Jute goods	9.7	-1.5	-1.4	6.4	0.7
Total raw jute and jute goods	6.8	-1.4	-1.4	8.3	0.4
Total export from Bangladesh	10.3	9.9	13.6	12.4	10.9

(in Per cent)

Jute ranks second only to cotton in amount produced. Traditionally Jute has been used as packing materials such as hessian, sacking, ropes, twines, carpet backing cloth etc. Nowadays Jute is being used in producing of various types of products. Diversified Jute products are being developed such as home textiles, technical textiles, geotextiles, agrotextiles, jute nonwovens, jute reinforced composites, pulp & paper, particle boards, shopping bags, handicrafts, fashion accessories, apparels etc[4].

Figure 15: Jute fiber extraction **Figure 16: Jute fiber is dried in Sun**
(source left image author Shahnewaz Karim, 2011)
(source right image author Auyon , 2011)

There are two Jute types in trade white (*Chorchorus capsularis)* and Tossa (*Chorchorus olitorius).* Tossa Jute is softer, silkier, and stronger than white Jute. It is also known as *Paat* in Bangladesh. Jute fiber is collected from the bast or skin of the Jute plant. That's why Jute fiber falls into bast fiber category. Jute plant grows in hot humid rainy alluvial lands. Jute plant is photo reactive, it harvests within 120 days[4]. It grows upto six to ten feet high. Matured Jute plants are cut, tied in bundle and put into slow flowing water for several weeks for fermentation. Jute fibers are pulled off from the bark, washed carefully and then dried in the sun.

Jute has huge ecological benefits. Jute plants purify air by assimilating CO_2. One hector of Jute plants can absorb 15 MT of carbon dioxide CO_2 and deliver 11 MT of fresh oxygen O_2 during 100days of Jute growing period. Studies reveal that CO_2 absorption rate of Jute is much higher than normal trees. Production of Jute is much less harmful compared to the production of synthetic fibers. Jute cropping enhance soil organic matter through leaf shedding during growing season. Jute cropping can be rotated with other food crops. Jute based multiple cropping enhance agricultural production. Rice, cereals, oilseeds, vegetables are benefitted from Jute cropping. Jute is a biologically efficient plant. Jute grows very fast within 4 to 5 months it matures and yields 8 to 12MT per hectare per annum. Jute requires very little quantity of fertilizer to grow. 7-53kg chemical fertilizers are used per hectare which is insignificant compared to other crops. Jute plant sheds 5-6tons of green leaves per hectare while growing which fertilize the soil[5].

Jute has thermal insulation properties as it has high specific heat. Ignition temperature of Jute is 193^{o}C. Jute fiber does not melt while charring or burning. Jute has also good resistance to electricity[6].

There are some disadvantages of Jute, which include poor drapability and crease resistance, brittleness, fiber shedding. Jute fiber becomes yellow in sunlight and decreases mechanical strength, due to the presence of higher lignin contents in Jute[7]. Due to the presence of hemicellulose in Jute fibers, it is hydroscopic. Jute fiber swells on absorption of water, decreasing tenacity of the fiber6. Jute fiber becomes subject to microbial attack in humid climates. Jute fiber strength and durability can be increased various levels through different surface treatments such as alkali treatment, silane treatment, isocyanate treatment, latex coating, permanganate treatment, acetylation, monomer grafting under UV radiation etc[8].

3.2 Properties of Jute.

Jute is a cellulose based material. It is stiff and yellowish in color due to the presence of hemicellulose and lignin. Each Jute fiber is composed of smaller units known as fibrils. They are arranged in right handed spirals and make closely held molecular chains which known as micells[9]. The chemical composition of jute is as follows—

Alpha Cellulose	58-63%
Hemicellulose	21-24%
Lignin	12-14%
Pectin	0.2-0.5%
Fat & Wax	0.4-0.8%
Protein	0.8-1.5%
Mineral Materials	0.6-1.1% (Abdullah 2008)

Table 2: Typical Properties of Jute Fiber (Ramaswamy and Aziz 1982)

Fibre length, mm	180 - 800
Fibre diameter, mm	0.10-0.20
Specific gravity	1.02- 1.04
Bulk density, kg/m^3	120 - 140
Ultimate tensile strength, N/mm^2	250 - 350
Modulus of elasticity, kN/mm^2	26-32
Elongation at break, (%)	2-3
Water absorption, (%)	25-40

Jute is relatively stiff and has high strength than other natural fibers.

Table 3: Properties of jute fibre in comparison with other fibres (reported in Doan Thi Thu Loan, 2006)

Fibre	Density (g/cm3)	Tensile Strength (MPa)	Young's Modulus (GPa)	Elongation At break (%)	Specific Tensile Strength (MPa/ g.cm-3)	Specific Young's Modulus (GPa/g.cm-3)
Jute	1.3-1.45	393-773	13-26.5	1.16-1.5	286-562	9-19
Flax	1.5	345-1100	27.6	2.7-3.2	230-773	18
Ramie	1.5	400-938	61.4-128	1.2-3.8	267-625	41-85
Sisal	1.45	468-640	9.4-22.0	3-7	323-441	6-15
Coir	1.15	131-175	4-6	15-40	114-152	3-5
E-glass	2.5	2000-3500	70	2.5	800-1400	28
S-glass	2.5	4570	86	2.8	1828	34

1. Mudassir Rashid, "Bangladesh decoded Jute's genome sequencing 'Golden fiber to redeem the lost glory'", Bangladesh Textile Today, Jul-Aug 2010.
2. World Export report of raw Jute, Kenaf and allied fibers from 2003/2004 to 2009/2010, Food and Agriculture Organization (FAO)
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4. Dr A.B.M. Abdullah,"Jute Geotextiles and Their Applications", Jute Diversification Promotion Centre (JDPC), Dhaka, June 2008.
5. "Environmental Impact of Jute Agriculture", International Jute Study Group (IJSG), http://www.jute.org/ecology.htm accessed on 14-11-12

3.3 Jute Fabrics

Different types of Jute fabrics are manufactured in in spinning and composite mills with conventional spinning and looms. Depending on drafts, twists, dollop weight, design such as plain, twill, basket, satin/steen with closed, dense and open structure wide range of fabrics can be produced with different strength, thickness, porosity and permeability. Composite types of fabrics such as Jute-cotton union fabric are also produced with different ratio.

Figure 20: Hessian Jute fabric

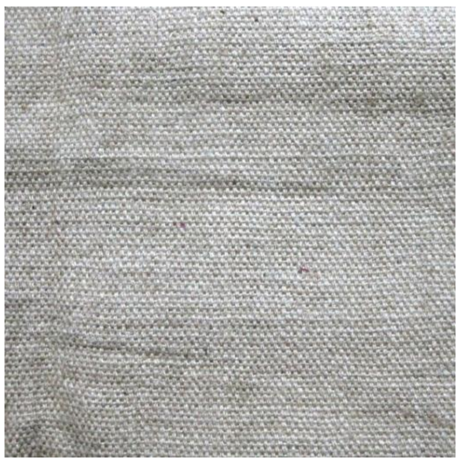

Figure 20: Jute canvas fabric.

Figure 20: Jute Double Warp (D.W.)

Figure 20: 50:50 Jute-cotton union

Following Jute fabrics are commonly used and available in market hessian, canvas, D.W twill, Jute-cotton blend. Hessian is the most porous; canvas is very closely woven with flat type yarn and least porous. Double warp (D.W.) twill is also known as A-twill, which is a 2/1 twill weighing 750 g/m^2 and widely used for packaging purposes[10].

3.3.1 Jute Geotextiles (JGT)

High strength Jute fabrics are now used as geotextiles. Jute geotextiles (JGT) are applied in various civil engineering projects. For example Rokeya shoroni link road was constructed in December 2008 in Dhaka[11]. Jute geotextiles are now becoming strong alternative to synthetic geotextiles. Though Jute geotextiles (JGT) are quickly biodegradable, but their life span can be extended up to 20yrs through proper treatment and blendings[12]. JGTs are anionic, harmless, and soil fertilizer. They are used in different purposes such as erosion control, soil filtration and drainage, soil stabilization and fertilization etc. A comparison is presented in the table between various types of untreated, bitumen treated JGT and synthetic geotextiles.

Table 4: Test result of treated JGT, untreated JGT and synthetic geotextiles (reported by Jabbar, 2008)

Product	Condition	Mass per unit area (g/m2)	Thickness (mm)	Wide width tensile strength (kN/m)	Grab tensile strength (N) MD/XMD	CBR puncture resistance (N)	Burst strength (kPa)	Permitivity (S–1)	AOS (mm)
Jute	Treated	1600	3.5	15/18	800/700	4000	1500	0.06	0.0 to
	Untreated	800	2.8	10/12	400/220	1500	1250	0.28	0.28
Canvas	Treated	1200	2.5	27/15	1100/700	1800	1600*	0.0	0.0 to
	Untreated	500	1.3	23/14	850/400	1700	2400	0.03	0.09
DW Twill	Treated	1400	3.1	25/32	1000/900	1700*	2600	0.21	<0.075
	Untreated	750	2.4	23/26	900/750	4500	2400	0.25	0.8
Hessian	Untreated	300	1.5	12/14	210/220	1500	1400	1.19	1.0
Synthetic	Non-Woven Geotextiles	240-640	2.0-4.5	[18-48] /[15-31]	[1160-2590]	2660-5450	3800-4500	0.4-1.8	

6. Tapobrata Sanyal, “Jute & Jute Geotextiles”, http://www.jute.com:8080/c/document_library/get_file?uuid=87c9f7ad-ddc6-4b36-9cae-ecf4edd456ec&groupId=22165 Accessed on 14-11-2012
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3.3.2 Jute-Cotton Union fabrics

In Jute-cotton union fabric, cotton yarn is normally used in warp direction and Jute is used in weft direction. Jute-cotton union fabrics are cheaper than 100% cotton fabric because of Jute in it. It has a great potential to replace 100% cotton fabric. Jute-cotton union fabrics are now used as carpets, rugs, floor covering.

3.4 Strength Test

For tensile strength testing purposes, one side Polypropylene (PP) laminated untreated hessian Jute 13x13, 15x15 and 50:50 Jute-cotton union fabric have been collected from Jute Diversification Promotion Center (JDPC) Dhaka. And they have been tested in Geotech Lab of Dept. of Civil Engineering, Bangladesh University of Engineering & Technology. Strip tensile strength was done according to ASTM D4595. Report is attached in appendices.

Figure 23: One side laminated (13x13) Jute-fabric

Figure 23: 50:50 Jute-cotton blend

Figure 23: One side laminated (15x15) Jute-fabric

Table 5: Tensile strength test result

Fabric sample	Chemical treatment	Weave construction	Average mass per unit area gm/m2	Yarn count Jute tex	Thickness, mm	Strip tensile strength MD/XMD kN/m	Strip tensile elongation MD/XMD %
(13x13) Jute fabric natural	untreated	Plain weave	376	256	.88	15.4/16.7	10/10
(15x15) Jute fabric natural	untreated	Plain weave	331	150	.756	14/12	12/8
Jute-Cotton 50:50 union	untreated	Plain weave	2213	95	1.025	18.1/15.2	4/22

From the strength test it is found that one side laminated (13x13) Jute fabric has more tensile strength than (15x15) Jute fabric. Tensile strength of Jute-cotton fabric is the highest among three fabrics, since it has cotton in it.

(15x15) Jute fabric has more elongation in MD than (13x13) Jute fabric but less elongation in XMD direction. On the other hand Jute-cotton fabric elongation in XMD is the highest and in MD is the lowest, because of the use Jute in XMD direction and cotton in MD direction.

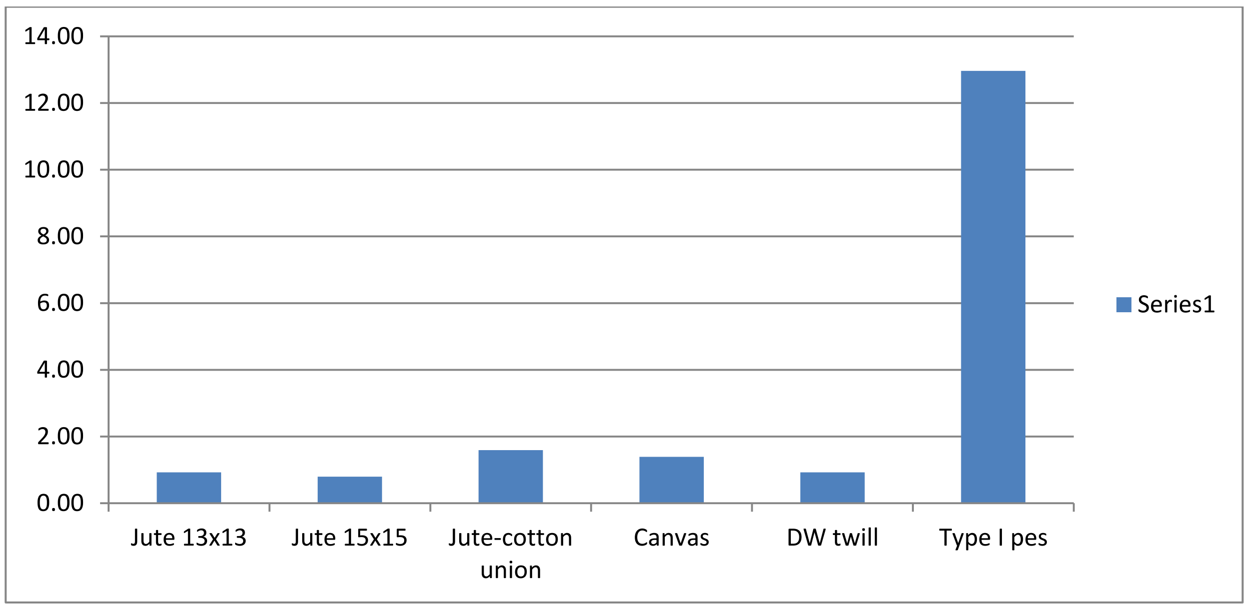
Jute-cotton union fabric has the highest mass per unit area and thickness among the three fabric tested.

10. Jute products: sacking, http://www.jute.org/jute_prod_sac.htm accessed on 16-11-12
11. Prof. Dr. Abdul Jabbar Khan, Major Md Masudur Rahman, “A JGT Reinforced Road Subgrade In Bangladesh”, http://www.fibre2fashion.com/industry-article/21/2028/a-jgt-reinforced-road-subgrade-in-bangladesh1.asp accessed on 14-11-12
12. Dr A.B.M. Abdullah,”Jute Geotextiles and Their Applications”, Jute Diversification Promotion Centre (JDPC), Dhaka, June 2008.

3.5 Cost Comparison

Cost comparison of laminated Jute, Jute-cotton union fabric, Canvas, DW twill in €/m^2 is given below.

Table 6: Recent market cost comparison of different Jute fabrics €/m^2



From the above chart we can see that cost of Type I PES is almost 14 times higher than one side laminated Jute 13x13 in local market, because of the local production and availability of Jute fabric. Prices of Jute fabrics are collected from JDPC (Jute Diversification and Promotion Center) of BJRI (Bangladesh Jute Research Institute).

3.6 Review of Recent Research and Developments

Diverse Jute based products are now produced. New researches and technologies are being developed to enhance the quality of Jute products. Some recent research and developments in this field are mentioned below.

A group of Bangladeshi scientists led by Dr. Prof. Dr. Maqsudul Alam have successfully disclosed Jute genome sequencing. It is a great leap for Jute development. Jute plants are affected by flood, saline soil and different types of pest and diseases that harm cultivation. By developing Jute genome it is possible to develop high yielding, flood resistant, saline soil and pest tolerant Jute.

Jute is now used in housing sector, replacing traditional material. Research group of Bangladesh Atomic Energy Commission (BAEC) has developed JUTIN, which is produced from jute (hessian cloth), and resin. JUTIN is durable, rustproof, saline-resistant, lightweight, heat-resistant, and environment friendly. It is 40.2% cheaper than existing alternatives. It may replace traditional corrugated iron (CI) sheets. JUTIN will play a major role in housing sector of Bangladesh[13].

Figure 24: Jutin (Md Saimum Hossain, Energy Efficient and Low-cost Housing Material, 2010)

Jute fiber is also used in ecofriendly boat making. A 9m long eco-friendly boat ecofriendly boat made of 40% jute and 60% fiber glass is built Taratari shipyard near Dhaka. It is designed by French naval architect Marc Van. Corentin de Chatelperron set sail on this boat from Bangladesh to France in September 2010[14].

Due to biodegradability of Jute, durability of Jute products is short. But recent study show that latex treated Jute can last upto 20yrs[15].

13. "Local researchers develop jute-made substitute for CI sheet", http://www.thefinancialexpress-bd.com/more.php?news_id=97298&date=2010-04-10 accessed on 14-11-12
14. http://tibotaratari.wordpress.com/2010/09/15/taratari-corentin-voiles-et-voiliers-video/ accessed on 14-11-12
15. Dr. A. B. Jabbar Khan, "Quality Control of Jute Geotextiles & Development of Testing Facilities", http://www.jute.com:8080/c/document_library/get_file?uuid=f1d0dc40-69a9-490c-89c8-ca05dede6918&groupId=22165 accessed on 14-11-12

Table 7: Summary of jute blended with different materials at BJRI (reported in Jabbar, 2008)

Type	Composition	Poss. durability	Biodegradability	Moisture content	Wt./unit gm
Woven Jute in different structure/ design	All Jute (untreated)	6-9 month	Quick	12-14%	220-800
Woven Jute in different design/ Construction	Jute treated with coir	9-12 month	Slow	7-10%	220-800
Woven Jute but treated composite	Jute treated with Bitumin carbon	9-48 month	Long run	3-8%	Var. wt.
Woven Jute in different Construction/ design	Jute treated with Latex	5-20 years	Long run	5-7%	≥ 800

Jute fiber becomes brittle and loses its strength in prolonged exposure to sun. To protect it from UV radiation several treatments and dyes have been developed. One example is monochlorotriazinyl reactive dye with cyanuric chloride nucleus, such as Cibacron Red FAL which is found to be effective in UV protection. Simultaneous dyeing and finishing with Cibacron Red FAL and Cibatex UPF provides higher UV protection. The treatment of jute/cotton fabric with titanium dioxide also provides satisfactory protection against UV rays[16].

Due to hydroscopic behavior of Jute, it attracts water. Water uptake can significantly reduce tenacity.
Water uptake of Jute fiber can be significantly reduced through treating fiber surfaces by NaOH/(3-Aminopropyl-triethoxy-silane + Epoxy dispersion XB 3791) and NaOH/3-Phenylaminopropyl-trimethoxy-silane[17].

There is a growing interest on Jute reinforced polymer matrix composites, due to ecological aspects of Jute such as biodegradability, renewability, low energy, non-toxic, non-health hazardous as well as good thermal and electrical insulations, toughness, and market availability at low cost. Jute polymer composites such as Jute fiber reinforced polypropylene or epoxy, Jute-glass fiber hybrid composite, Jute fabric-Reinforced PVC-based composite, Jute viscose/polyester and cotton blended fabric, jute fabric-reinforced polyester composites are now used as panels, false ceiling, partition boards, wall, floor, window and door frames, roof tiles, furniture, electric devices, automobile and railway coach interior, boat, Toys etc.

A green Architectural membrane, based on Kenaf bast fiber has been developed by Taiyo Kogyo Crop. Kenaf is a natural fiber and have similar characters as Jute. Kenafine[TM], developed by Taiyo Kogyo Crop., is made by weaving Kenaf fiber with polyester fiber. This bas fabric is coated on top with photocatalyst TiO_2 and at bottom coated with antibacterial agent of silver. This environment friendly green membrane can be recycled to make paper product[18]. Thus it is a carbon-neutral product than 100% polyester based fabrics. Test result of Kenafine is given below.

Figure 25: Kenaf plant.
(source http://fabricarchitecturemag.com/repository/4/15396/full_1112_np9_1.jpg)

16. Ghosh S. B., Bajaj P., Kothari V. K. "Effect of dyes and finishes on UV protection of jute/cotton fabrics", Indian journal of fibre & textile research, vol. 28, no4, pp. 431-436, 2003
17. Doan Thi Thu Loan, "Investigation on Jute fibers and their composites based on polypropylene and epoxy matrices", page-112, Technischen Universität Dresden, May 2006.

Table 8: Test result of Kenafine™

Items	Test method	Measurement value
Mass (g/m^2)	JIS K 6404-2-2 ISO 2286-2	904
Thickness (mm)	JIS K6404-2-3	0.82
Flame retardancy	NFPA 701	M2(pass)
Flame retardancy	JIS A 1322 method B	grade2 (pass)
Tensile strength (N/3cm)	JIS L 1096	2470 x 2340
Tensile strength (N/5cm)	ISO 1421	3979 x 3734
Lap joint of tensile strength (%)	JIS L 1096	100
Tear strength (N)	JIS L 1096	229.6 x 271.7
Tear strength (N/mm)	DIN 53363	355 x 427
Tear strength (N)	ASTM D 751-06	156.1 x 193.8
Resistance to accelerated and outdoor exposure weathering	After UV irradiance for 416h	98 x 87
Decomposition activity index (nmol/L/min)	JIS R1703-2 Decomposition of wet methylene blue	20.9
Antibacterial activity	JIS Z 2801 Staphylococcus aureus Escherichia coli	 >5.0 >6.0

(Source http://fabricarchitecturemag.com/articles/1112_np9_material_research.html)

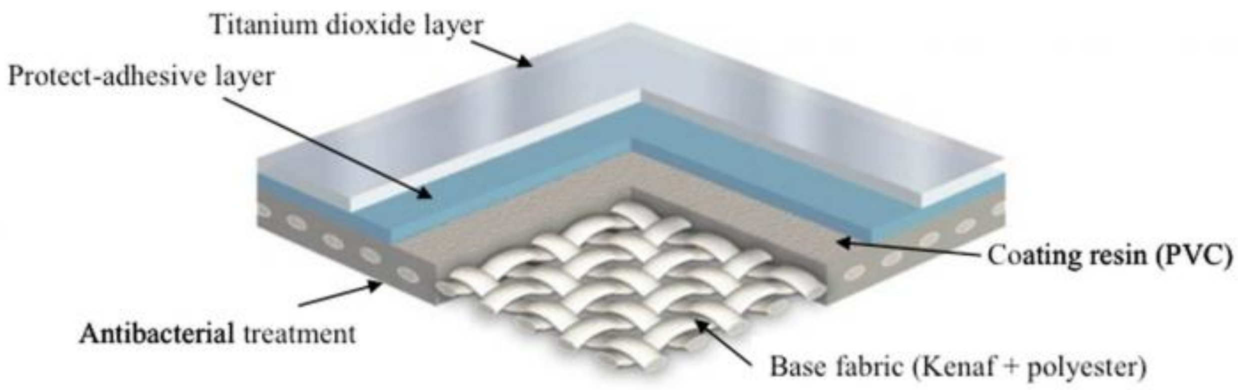


Figure 26: Structure of Kenafine™
(Source http://fabricarchitecturemag.com/articles/1112_np9_material_research.html)

18. H. Toyoda, "Recyclable coated fabric using kenaf fiber for architectural membrane structure applications", Fabric Architecture, November 2012, http://fabricarchitecturemag.com/articles/1112_wp_kenaf_fiber.html accessed on 16-11-12.

Chapter 04:

Design development

4.1 Project background

Dhaka Zoo is situated in north eastern part of Dhaka. It was established in June 1974. It is the largest zoo in Bangladesh. It has an area of 75.53 hector with north and south lakes[1]. Dhaka zoo holds 4th position in the world considering the land area of other zoos[2]. About 4 million visitors visit Dhaka zoo each year[1]. It is operated by Ministry of Fisheries and Livestock. To raise the standard of the zoo to an international level Ministry has taken initiatives for renewal and redevelopment plan for Dhaka zoo. Ministry is sponsoring Dhaka zoo modernization project from July 2010 to June 2015. It will be executed by Department of Livestock Services. The modernization project includes construction of 20 new visitor's shed in Dhaka zoo with an area of 25sqm for each[3].

Figure 27: Dhaka zoo satellite image. Source: Google earth

Figure 28: Existing visitor's shed in Dhaka zoo.

4.1.1 Project Requirement

20 visitors's shed design in Dhaka zoo.

Area of each shed will be approx. 25sqm.

4.1.2 Site Description

Site locations for proposed visitor's sheds have been identified based on their locations, which are close to walkaways, lakes and cases.

Figure 29: Site location for a prototype visitor's shed.

References:

1. History of Dhaka zoo, http://www.dhakazoo.org/history.html accessed on 13-11-12
2. BUET finalises clauses for zoo renovation master plan, Dilara Hossain, Bangladesh Sangbad Sangstha (BSS), 6 April 2012.
3. Dhaka & Rangpur Zoo Modernization Project, Development Project Proposal (DPP), Ministry of Fisheries and Livestock, July 2010

4.2 Conceptual Development

A prototype shed is developed which can be repeated in various sites with minor changes. Several ideas are sketched. Simplicity, lightweight structure, attractive sculptural quality and functionality are considered while designing visitors shed.

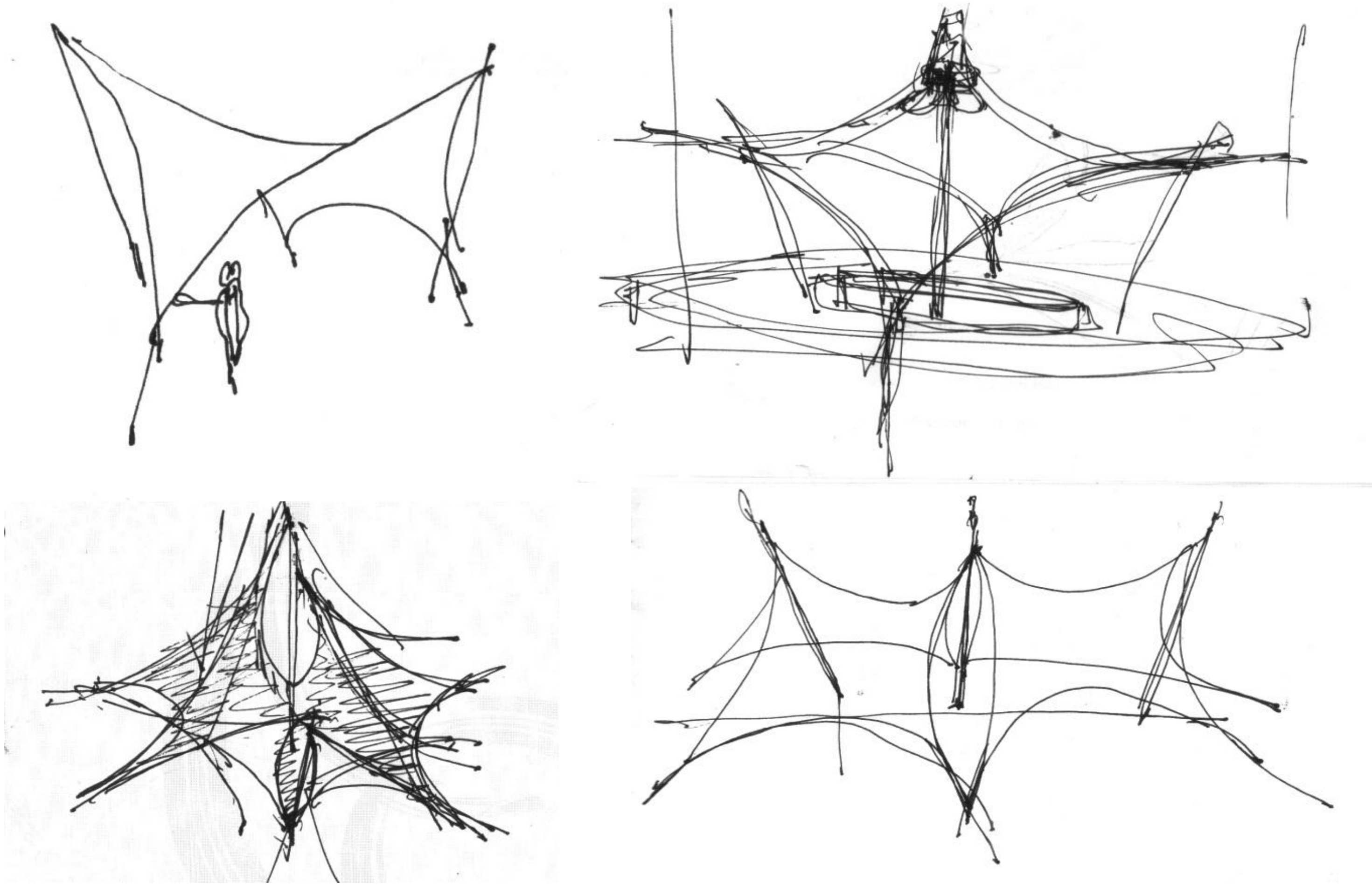


Figure 30: Some sketches of design development phases

A simple sculptural light form has been developed which gives good shadow. The fabric is supported mainly by two high masts, two low masts and cables. Masts are connected by safety cables. At the low points water will be collected and collection points will be designed.

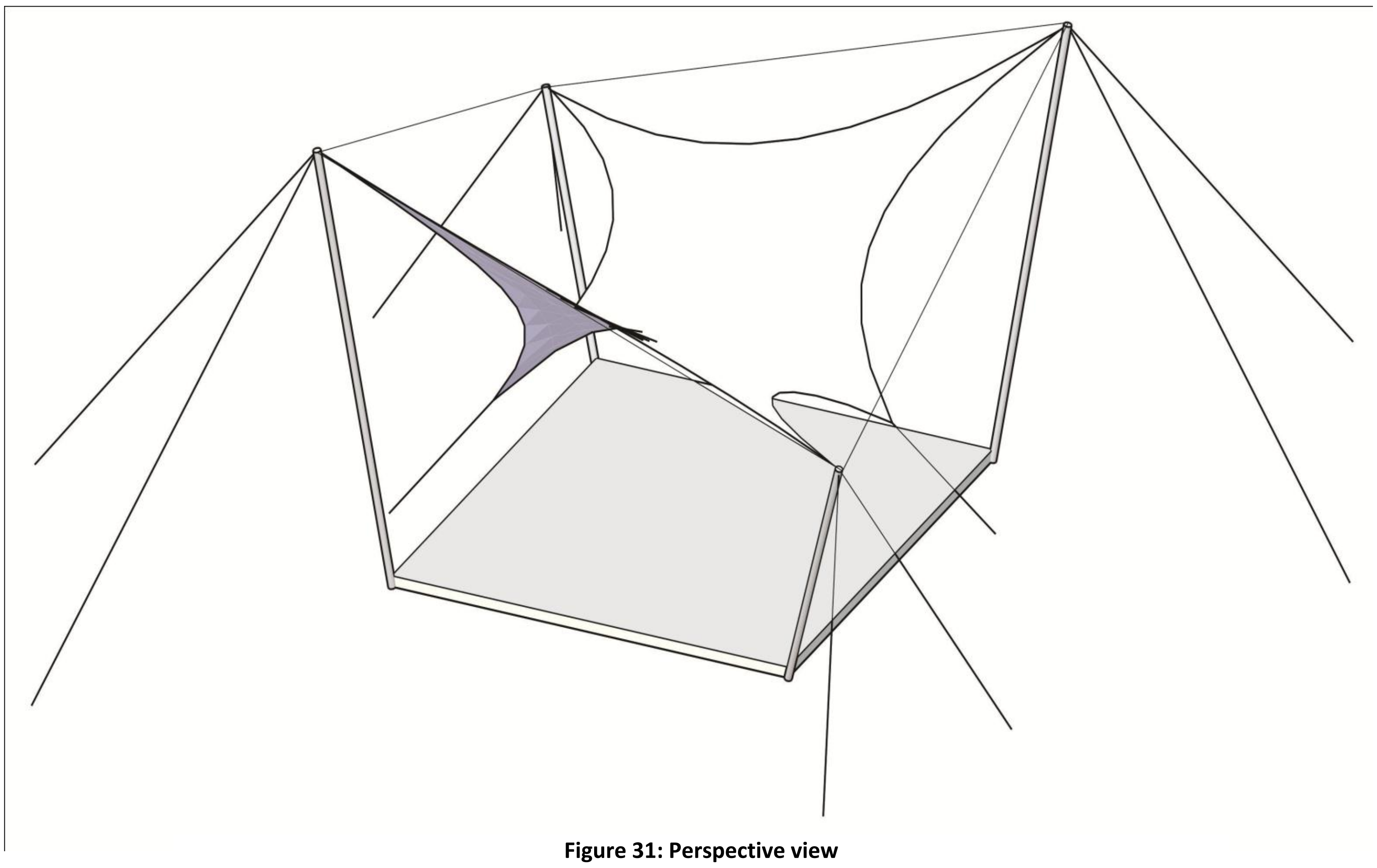


Figure 31: Perspective view

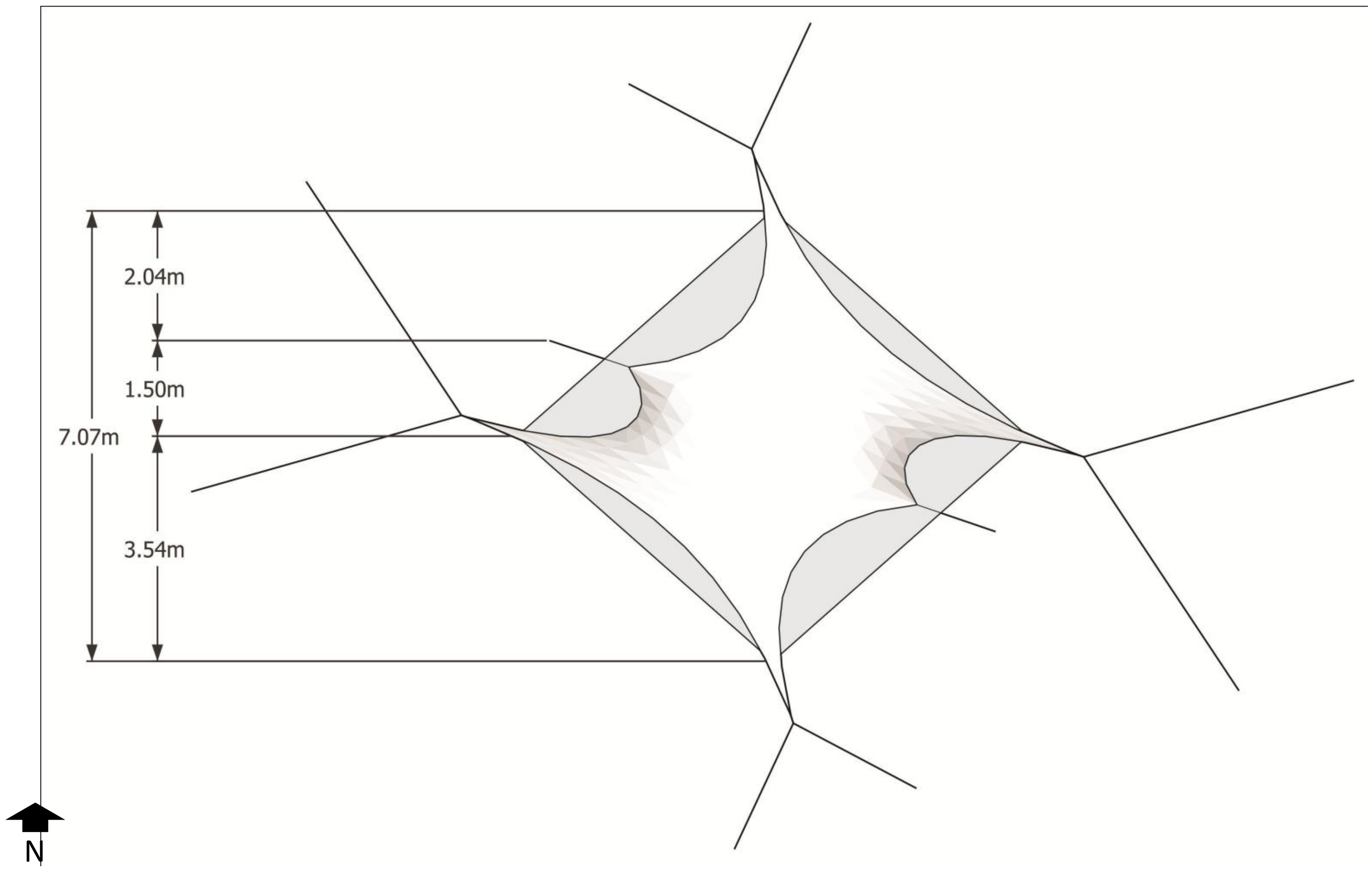


Figure 32: Plan

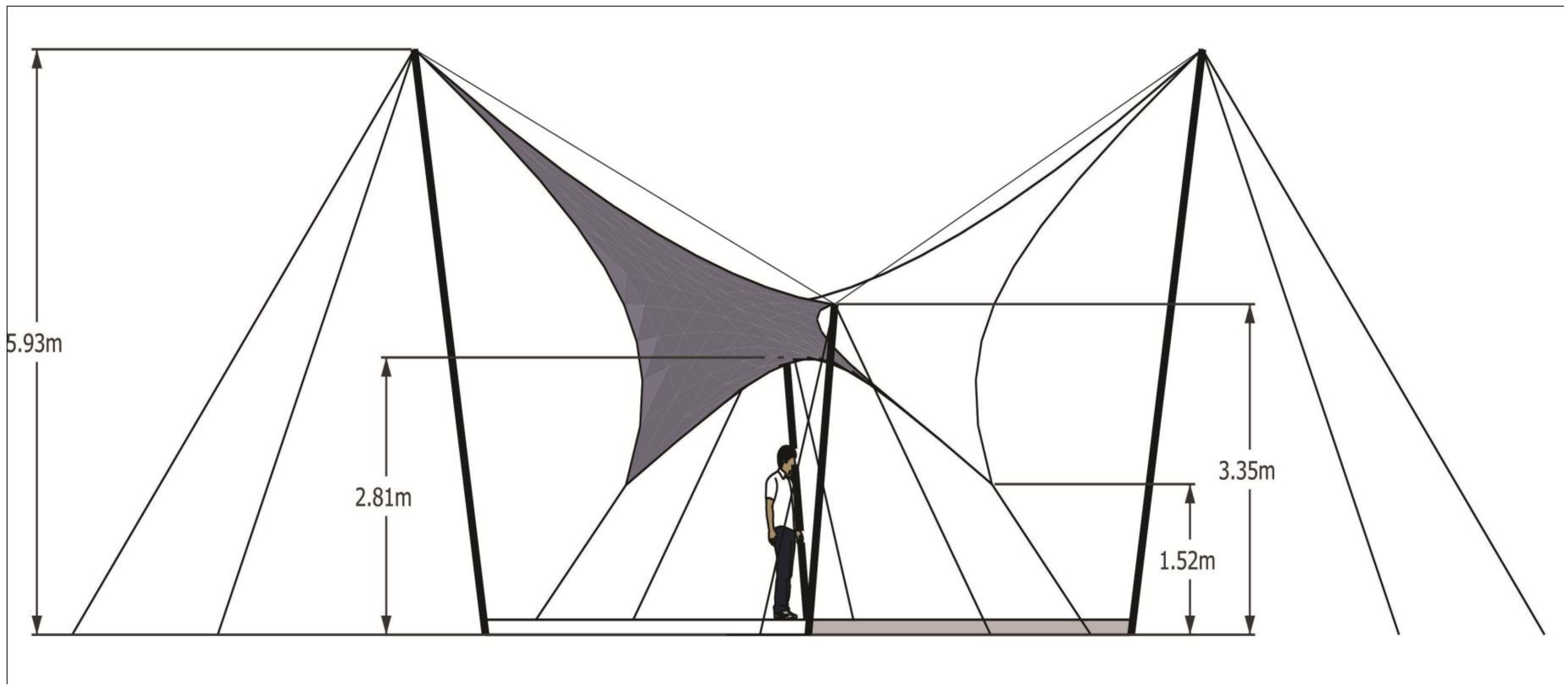


Figure 33: South Elevation

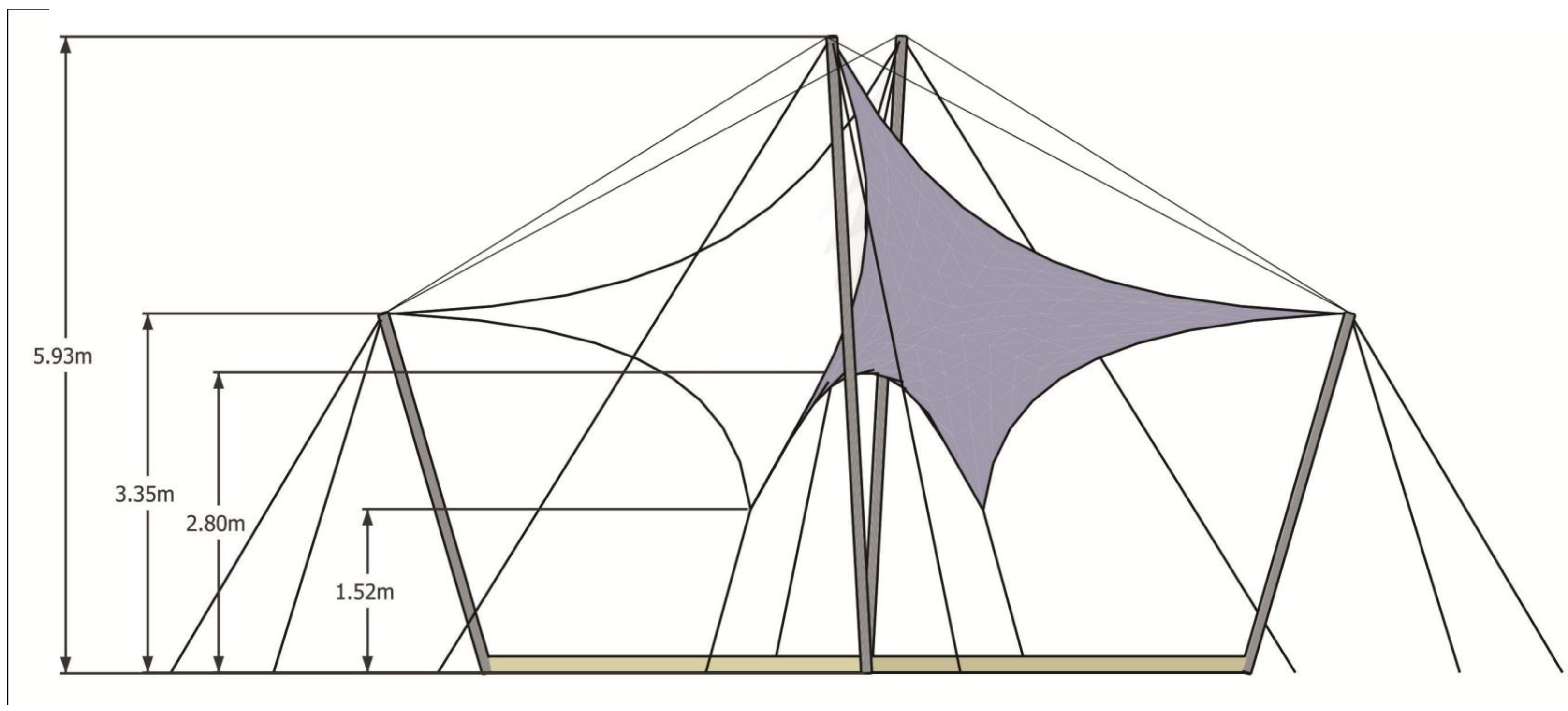


Figure 34: West Elevation

4.3 Physical Model Study

A physical model 1:50 scale has been made to study the surface shape, though achieving good shape is time consuming and laborious. It was made using cotton vest fabric, bamboo sticks and polyester thread.

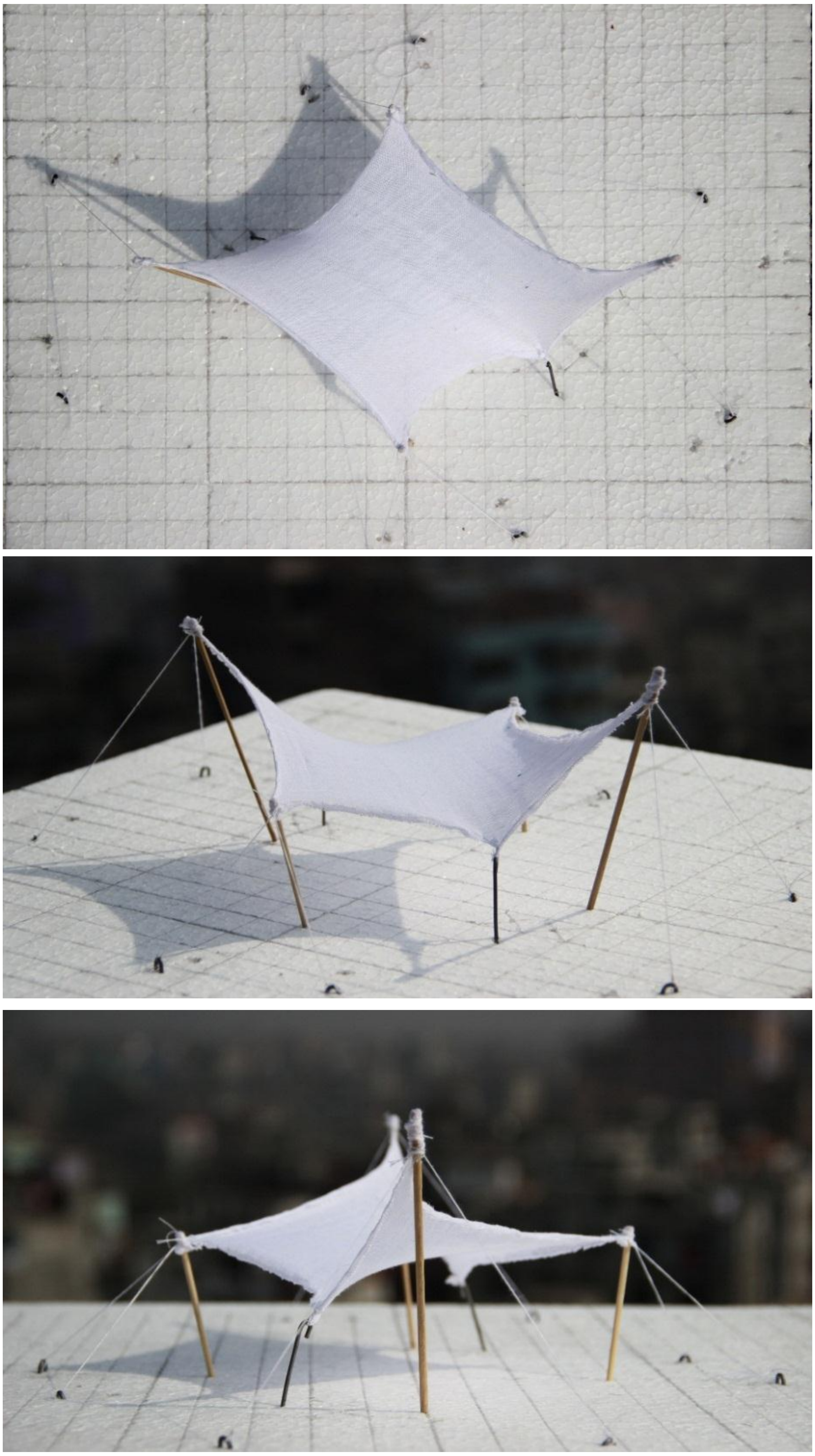


Figure 35: Physical model scale 1:50

4.4 Formfinding

Formfinding is a unique process for tensile membrane structures compared to traditional structures. It is finding basic static surface geometry of a tensile membrane structure within a given boundary configuration, before detail structural analysis. Concept of formfinding is based on 'minimal surface'. With minimal surface potential energy is a minimum, the shape configuration is stable. The ideal example of minimal surface with constant surface stress in nature is soap-films[4]. Because of the minimal shape any discontinuity or lack of tension will produce wrinkling, deformation and reduce life expectancy[5].

Numerical formfinding of the proposed structure was done by ixForten4000[6] software and boundary was drawn in Rhino[7]. A Jute fabric material is created in ixForten4000 using tensile strength 16.7kN/m in warp and 15.4kN/m in weft with elongation 10% in warp and weft which is based on test result in BRTC, BUET lab. Materials and properties of different elements during formfinding are given below.

Table 9: Properties of different elements in formfinding

	Tesnso Group			Membrane	
	Stay cables	Safety cables	Mast	Fabric	Edge cables
C values	NA	NA	NA	0.7	1.4-0.7
Seed	cable 16	cable 6	R100t13	**Jute fabric**	cable6
Material	Steel Cables	Steel Cables	S235		Steel Cables
Type	Cable	Cable	Truss	Membrane	Cable
Deformability	NL-Deformable	NL-Deformable	NL-Deformable	FDM-Deformable	FDM-Deformable
Behavior	Non-Linear	Non-Linear	Non-Linear	Non-Linear	Non-Linear

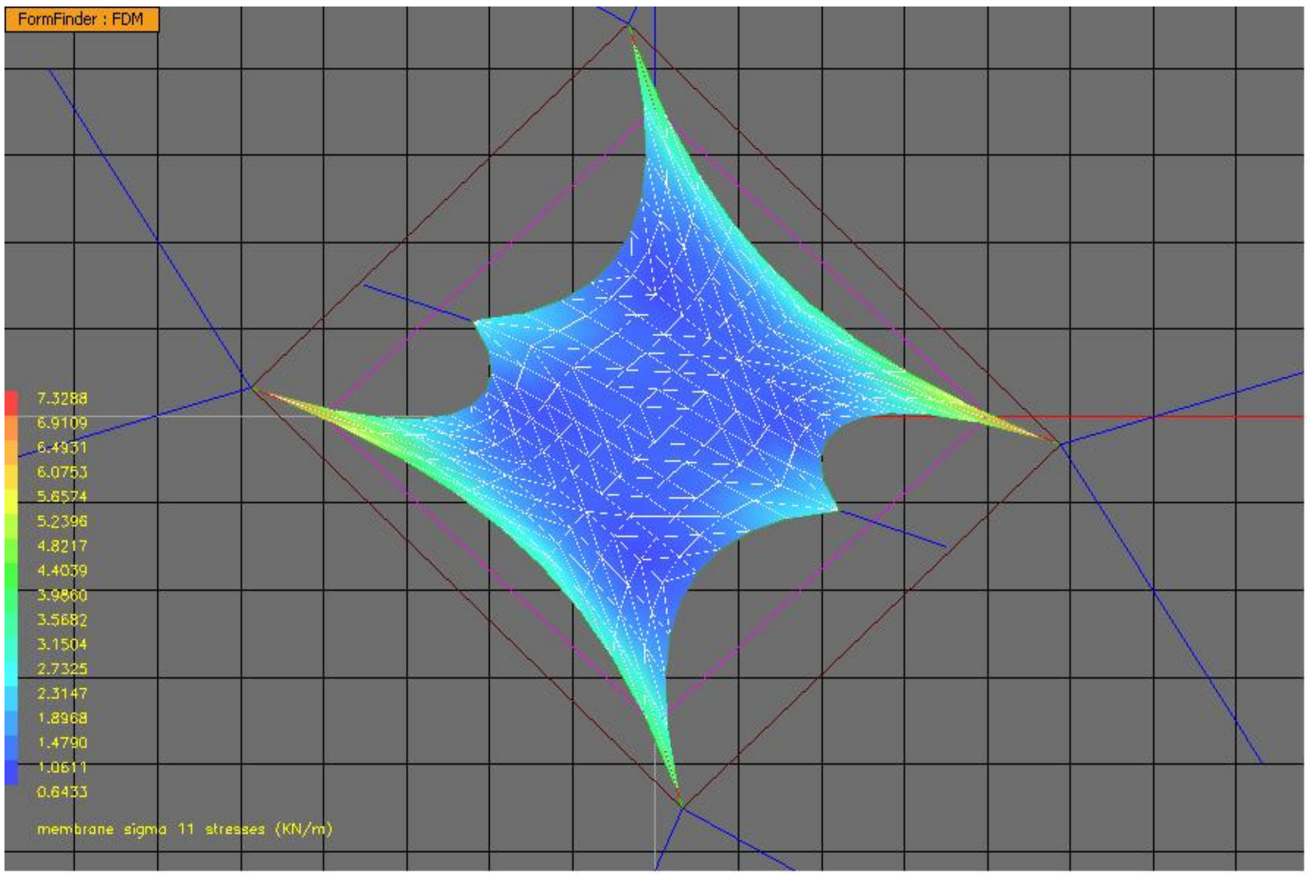


Figure 36: S-11 stresses after formfinding

4. W J Lewis, Tension structures: Form and Behavior, Thomas Telford, London, 2003
5. Jurgen Bradatsch, Peter Patzold, Cristiana Saboia de Freitas, Rudi Scheuermann, Juan Monjo, Marijke Mollaert, Form, European Design Guide for Tensile Surface Structures, Tensinet, 2004.
6. ixForten4000 version R 4.2.6, developed and copyrighted by Gerry D'Anza
7. Rhinoceros 4, Education version, developed and copyrighted by Robert McNeel and Associates

Overall sigma 11 stress, after formfinding is found to be 1.47 kN/m. Stress in corners is higher.
Sigma 22 stresses are comparatively lower than sigma 11 stresses.

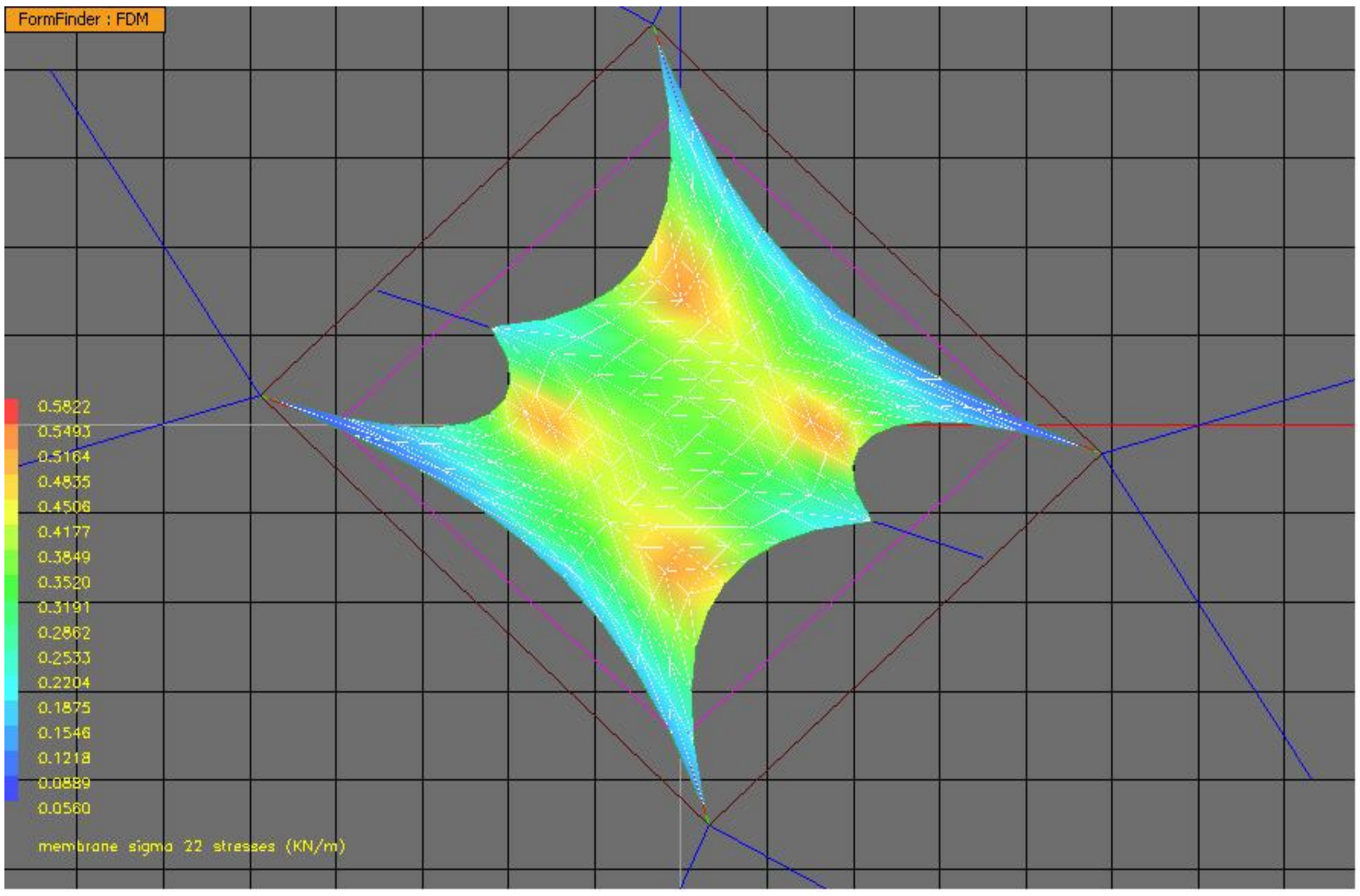


Figure 37: Sigma 22 stresses after formfinding

4.5 Shadow study

Shadow study has been made using Google Sketchup[8]. Geo location has been entered for Dhaka 23.7000° North, 90.3833° East. Since Dhaka is situated in tropic of cancer summer solstice June 21 is chosen to study shadow. During this period temperature is relatively higher and shadow becomes smaller. Shadows are studied for each hour from 8am to 4pm and juxtaposed to see the shadow patterns.

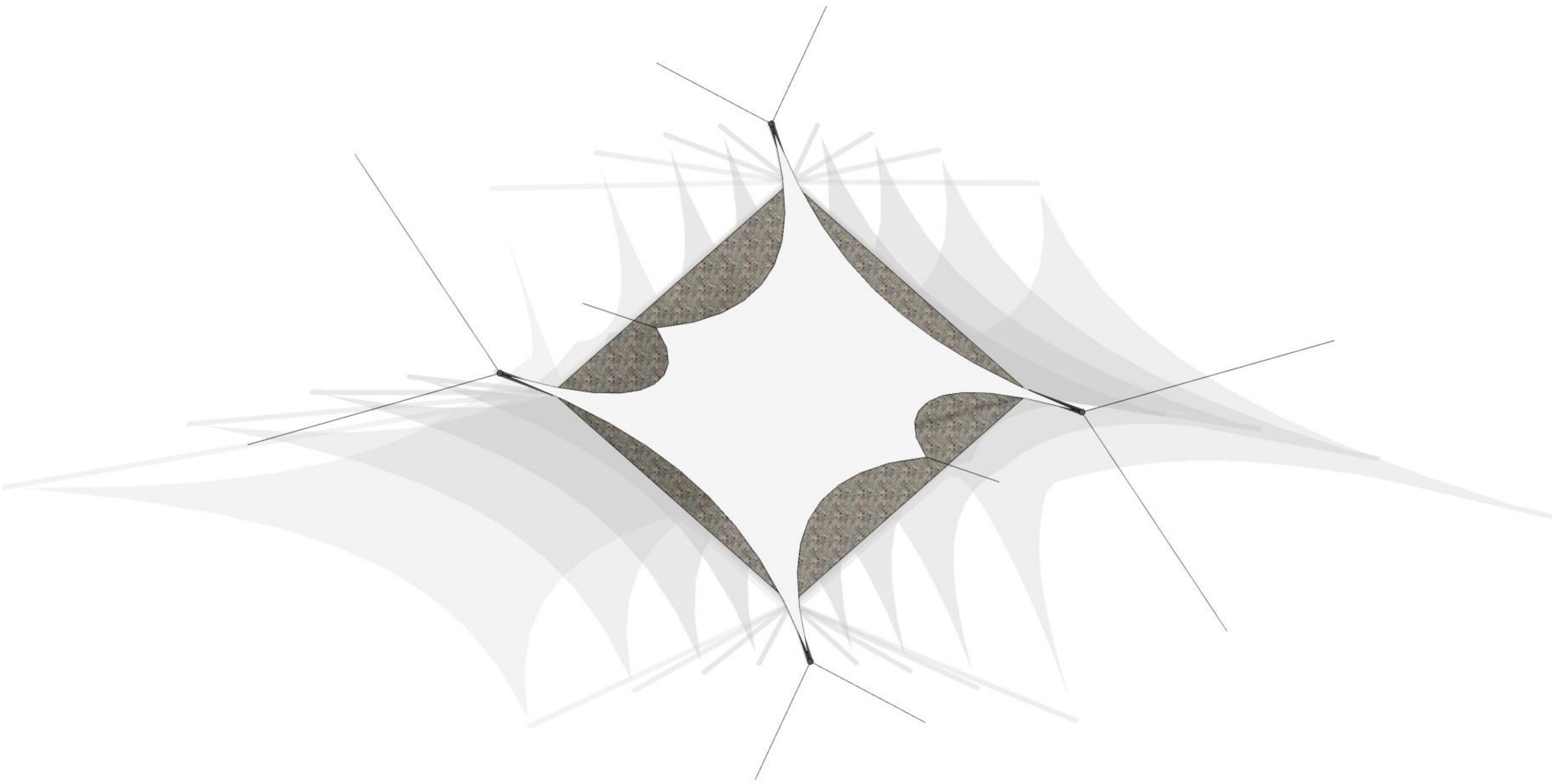


Figure 38: Juxtaposed shadows from 8am to 4pm

4.6 Membrane analysis

Non-Linear analysis of the membrane using different load combinations was done using ixForten4000[6].

4.6.1. Wind Load

Dhaka Zoo is located in Northwest part of Dhaka. Latitude and longitude of Dhaka is 23.7 and 90.38 respectively. Average annual wind flow is 2[8] (Beaufort scale). But Dhaka often experiences storms. Storms with 50-60 km/h are most frequent[9]. Basic wind speed 22.6 or Beaufort scale 9 is considered for the proposed membrane structure.

Basic wind speed V_b=22.6 m/s

Resulting wind pressure $q_b=\frac{Vb^2}{1600}$ kN/m^2 = **0.32** KN/m^2

According to eq. 4.8 of Eurocode 1991-1-4: Wind loads, Peak velocity pressure $q_p(z) = c(z)*q_p$
For a height (z) of 6m and terrain category III or suburban settings the exposure factor c (z) is 1.3
Then the peak velocity pressure $q_p(z)$= **0.42** KN/m^2

According to eq. 5.1 of Eurocode 1991-1-4: Wind loads, Wind pressure on surfaces $w_e = q_p(z) * c_{pe}$
Where, c_{pe} is external pressure coefficient. Pressure coefficient c_{pe} has been determined according to European Design Guide for saddle structure.

Table 10: Pressure coefficients for proposed membrane structure

Zones	Cpe values	Wind pressure KN/m2	Resulting pressure KN/m2
A	1.45	0.42	0.61
B	0.90	0.42	0.38
C	0.95	0.42	0.40
D	1.00	0.42	0.42
E	1.50	0.42	0.63
F	1.80	0.42	0.76
G	1.20	0.42	0.50
H	1.10	0.42	0.46
I	1.20	0.42	0.50
J	0.65	0.42	0.27
K	0.85	0.42	0.36

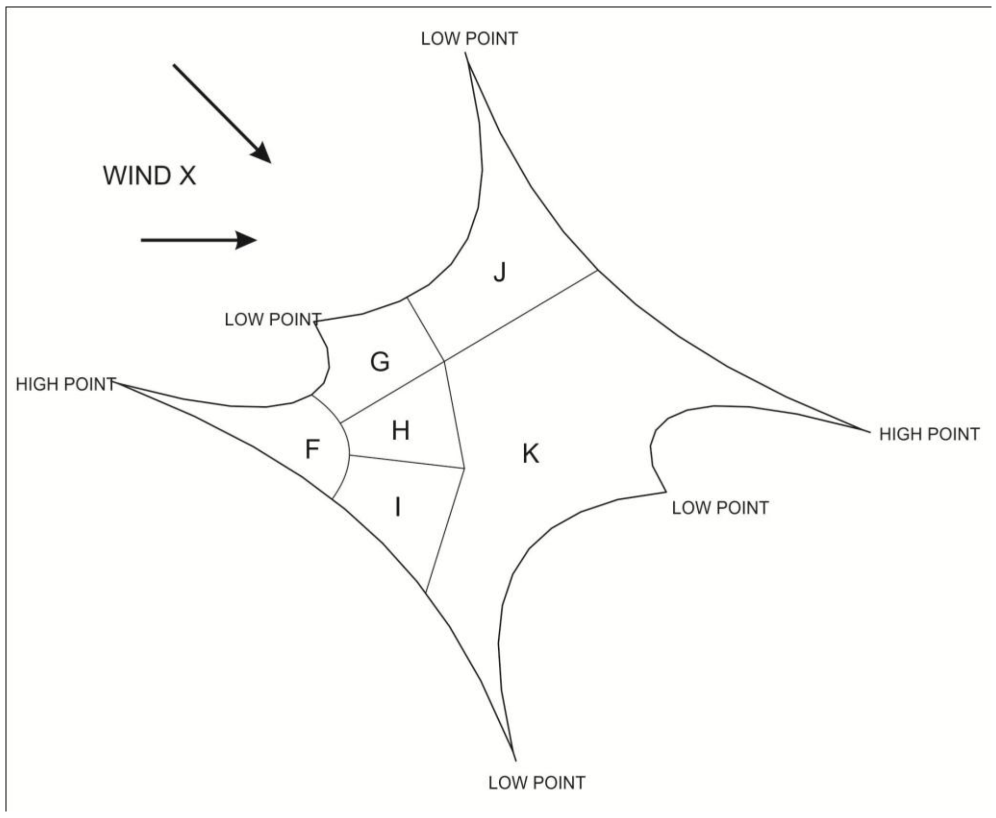


Figure 39: Cp Zone definitions for wind X direction

8. http://www.dhaka.climatemps.com/ accessed on 6-12-12
9. Samarendra Karmakar, Md. Mahbub Alam, Development Of Statistical Techniques For The Forecasting Of Nor'westers And Associated Maximum Gusty Wind And Rainfall Over Bangladesh, Journal of Bangladesh Academy of Sciences, Vol. 35, No. 2, 125-140, 2011

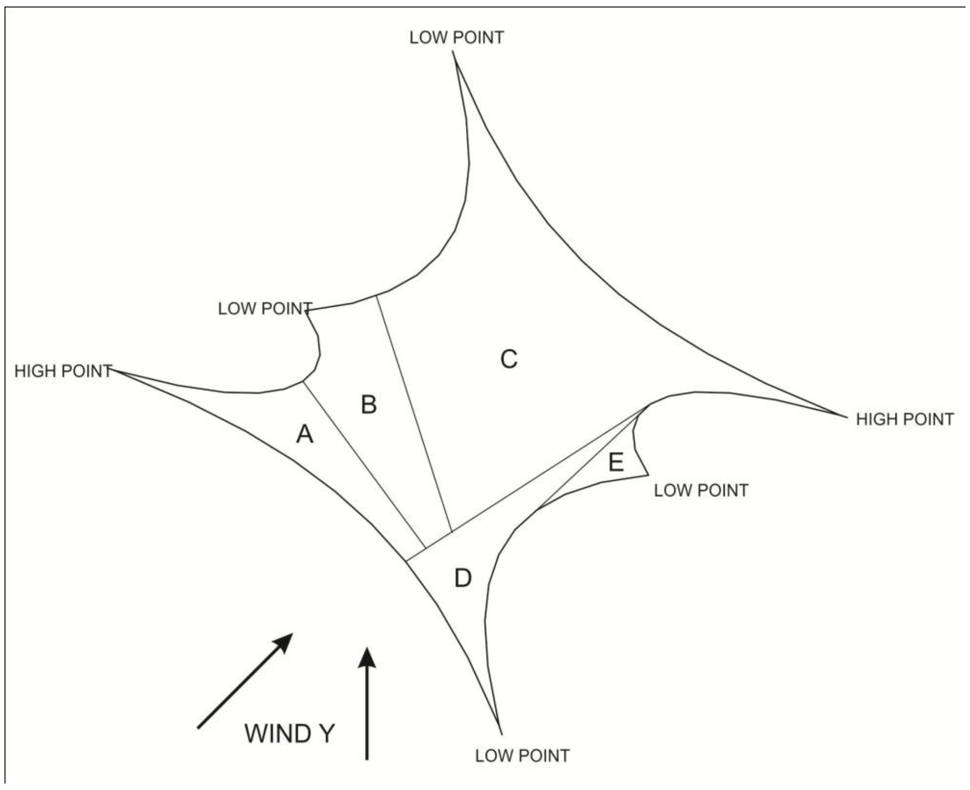


Figure 40: Cp Zone definitions for wind Y direction

4.6.2. Snow Load

Since there is no snow in Dhaka, therefore no snow load is considered.

4.6.3. Load Combinations

Load combinations are assumed according to DIN EN 1990

SLS
SLS-01: $1.0g+1.0v_0$
SLS-02: $1.0g+1.0v_0+1.0w$
SLS-03: $1.0g+1.0\ v_0+1.0w+1.0s$
ULS
ULS-01: $1.35g+1.35v_0$
ULS-02: $1.35g+1.35v_0+1.5w$
ULS-03: $1.35g+1.35v_0+1.35w+1.35s$

Where,
g = self-weight
v_0 = prestress
w = wind load (acting downwards or uplift)
s = snow load

In Serviceability Limit State (SLS) structure remains functional for its intended use under routine conditions or everyday use. In Ultimate Limit State (ULS) structure will not collapse, buckle or twist when it is subjected to maximum design load[10].

SLS			
	Self-weight	Wind X	Wind Y
SLS 01	1	0	0
SLS 02	1	1	0
SLS 03	1	0	1

ULS			
	Self-weight	Wind X	Wind Y
ULS 01	1.35	0	0
ULS 02	1.35	1.5	0
ULS 03	1.35	0	1.5

10. Prof Dr.-Ing. Lars Schiemann, Dr.-Ing. Karsten Moritz, Structural Design Concepts, IMS, September 2011

4.6.4. Maximum Stress and Membrane Selection

Maximum overall stress is found 4.45 KN/m in loadcase ULS03. Maximum stress 12.07 KN/m is located in corner where double layer of membrane is required.

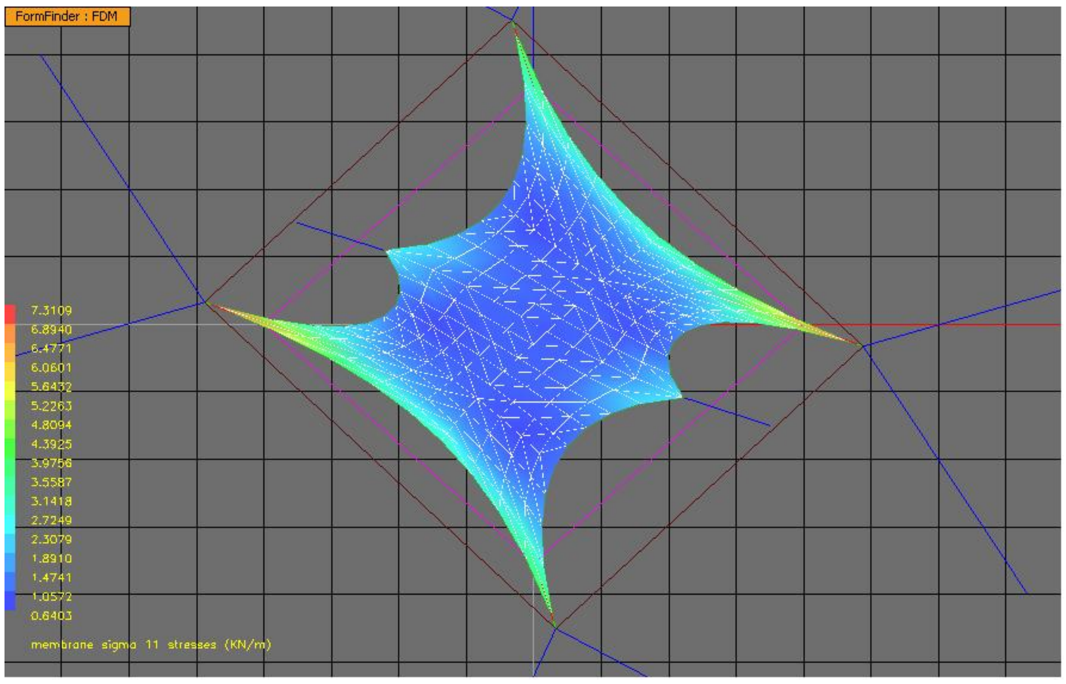


Figure 41: S-11 stress in loadcase ULS-3

Strength of the membrane degrades due to environmental conditions, temp., age, joining methods, creasing etc. Reduction factors for membrane material according to DIN 4134

	A factors				Resulting reduction factor
Loads	A_0	A_1	A_2	A_3	A_{res}
Permanent	1.2	1.6	1.2	1.2	2.76
Wind	1.2		1.2		1.44

Material safety factor for membrane Y_m=1.4
Then allowable strength $\mathbf{f_d= f_{tk} /(Y_m x\ A_{res})}$
Where f_{tk}= Tensile strength of the membrane

Allowable tensile strength of the laminated Jute membrane for permanent load

Direction	Tensile strength KN/m	Safety factor γm	Reduction factor Ares Prestress	Allowable strength KN/m
Warp	16.7	1.4	2.94	4.1
Weft	15.4	1.4	2.94	3.7

Which is ok, since overall stress after formfinding is 1.47KN/m

Allowable tensile strength of the laminated Jute membrane for wind load

Direction	Tensile strength KN/m	Safety factor γm	Reduction factor Ares wind	Allowable strength KN/m
Warp	16.7	1.4	1.44	8.3
Weft	15.4	1.4	1.44	7.6

Which is ok, since overall maximum stress found in loadcase ULS03 is 4.45KN/m.
So the laminated Jute fabric which has been selected as membrane material can withstand wind load and permanent load.

4.6.5. Displacement of The Membrane

There is a displacement of 28.73cm is found in loadcase SLS02. But no ponding area has been observed.

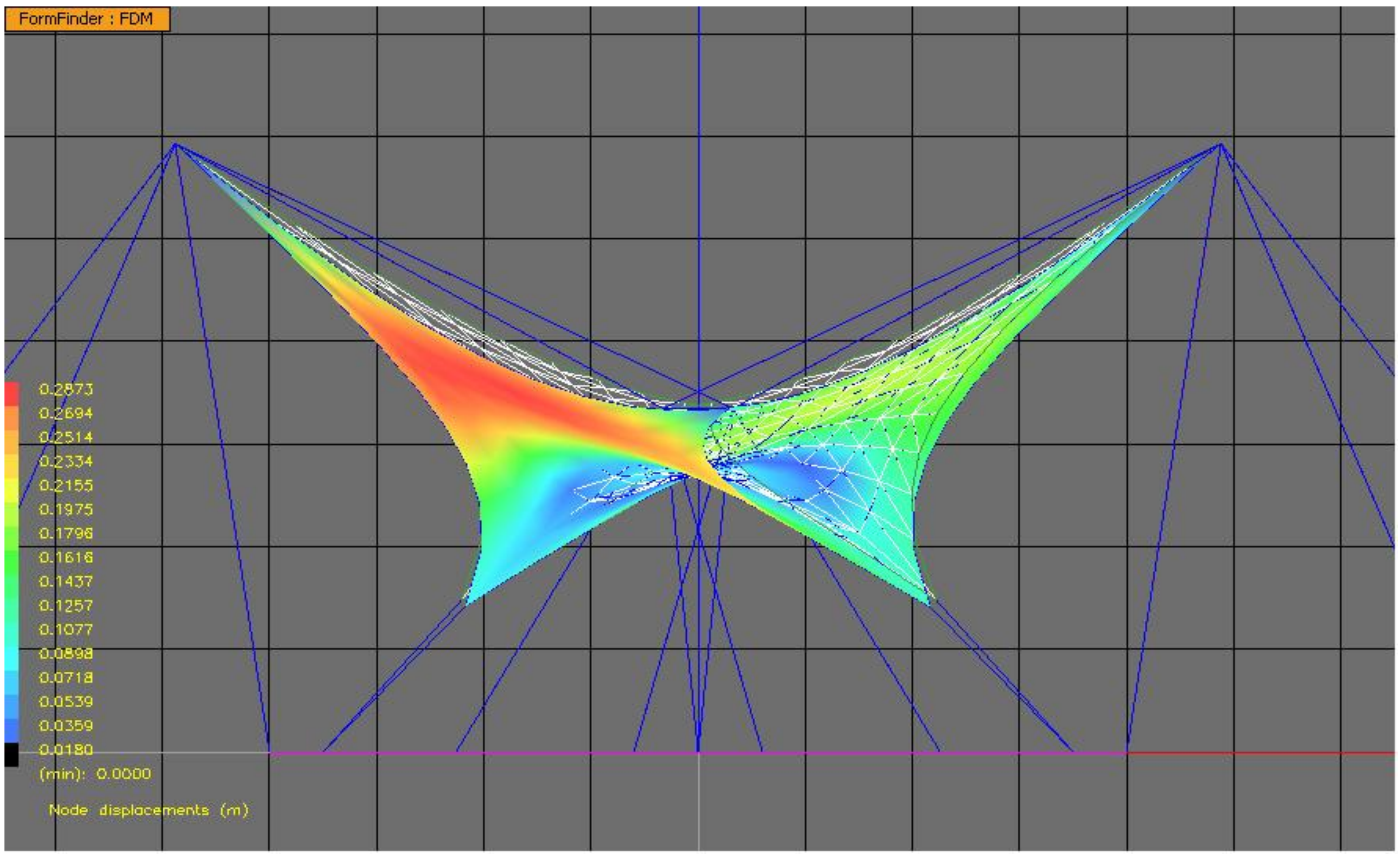


Figure 42: Displacement in loadcase SLS02

There is a displacement of 36.25cm is found in loadcase SLS03. But no ponding area has been observed.

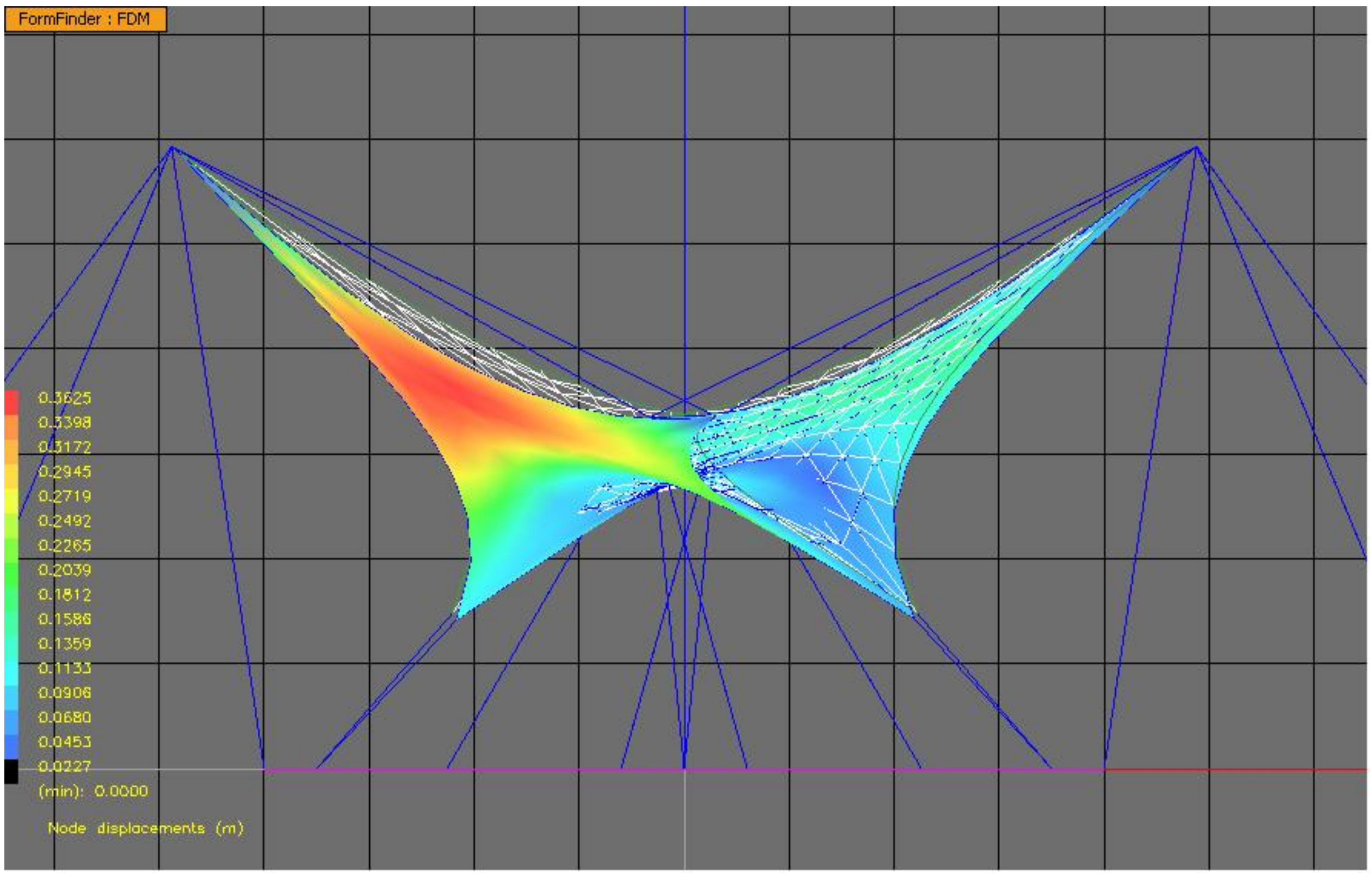


Figure 43: Displacement in loadcase SLS03

4.7 Patterning

To fabricate the membrane using 1.32m wide Jute 13x13 fabric, geodesic cutting lines are introduced on the surface of the membrane considering curvature of the surface, main load carrying paths, aesthetic reasons, fabric width. For avoiding wrinkling, material economy and accuracy geodesic cutting lines are generated on the surface of the membrane using ixForten4000. Geodesic lines on a curved surface are equivalent to straight lines on a plane. (Bletzinger 2008)

Patterns are made aligning warp of the fabric in hanging direction to take dynamic wind load while weft in arching direction. There are nineteen patterns ranging from 0.12m to 1.17m in width and 0.51m to 5.45m in length. A compensation of 0.3% corresponding test result has been taken into account in warp and weft.

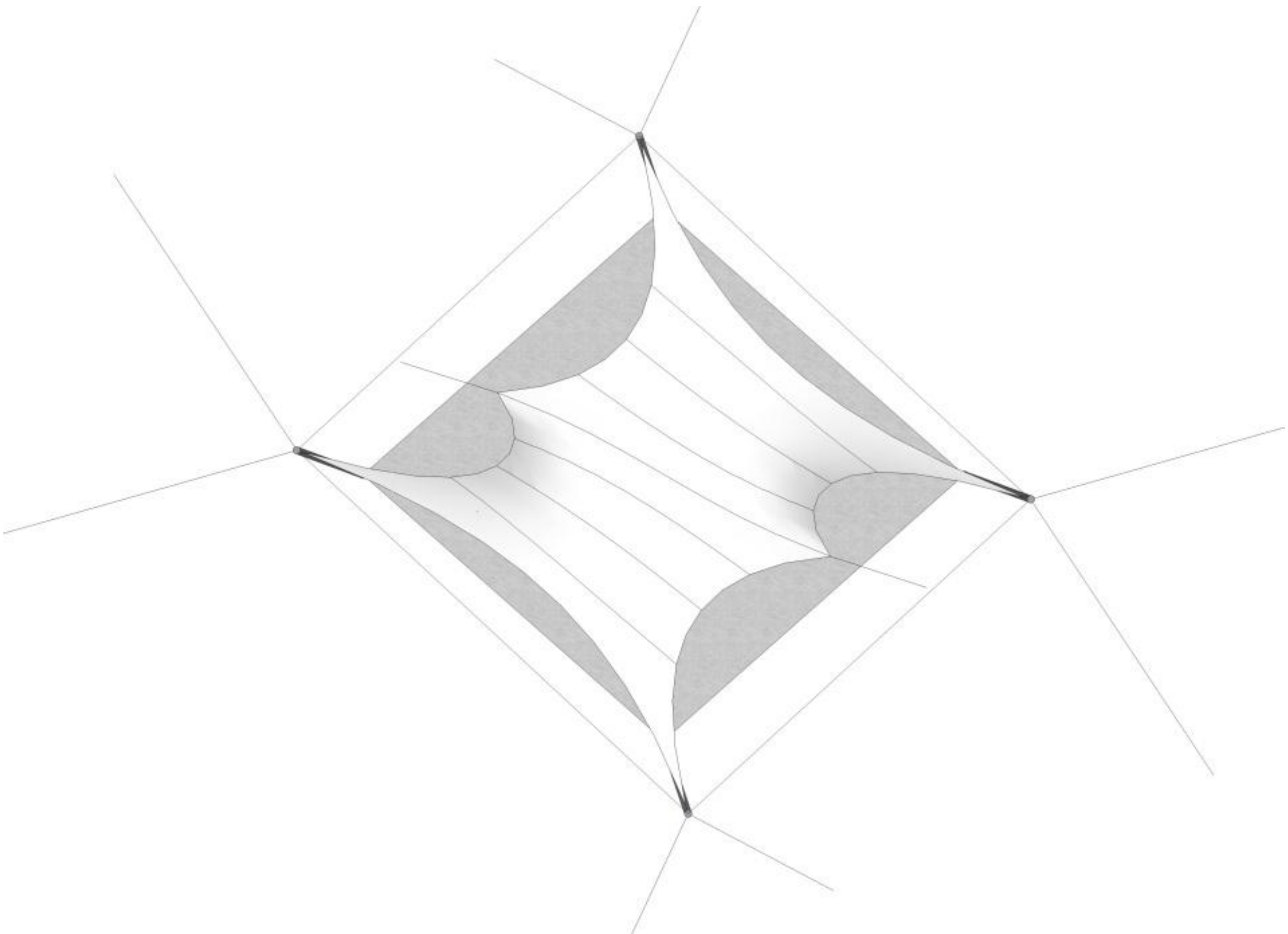


Figure 44: Top view of the pattern

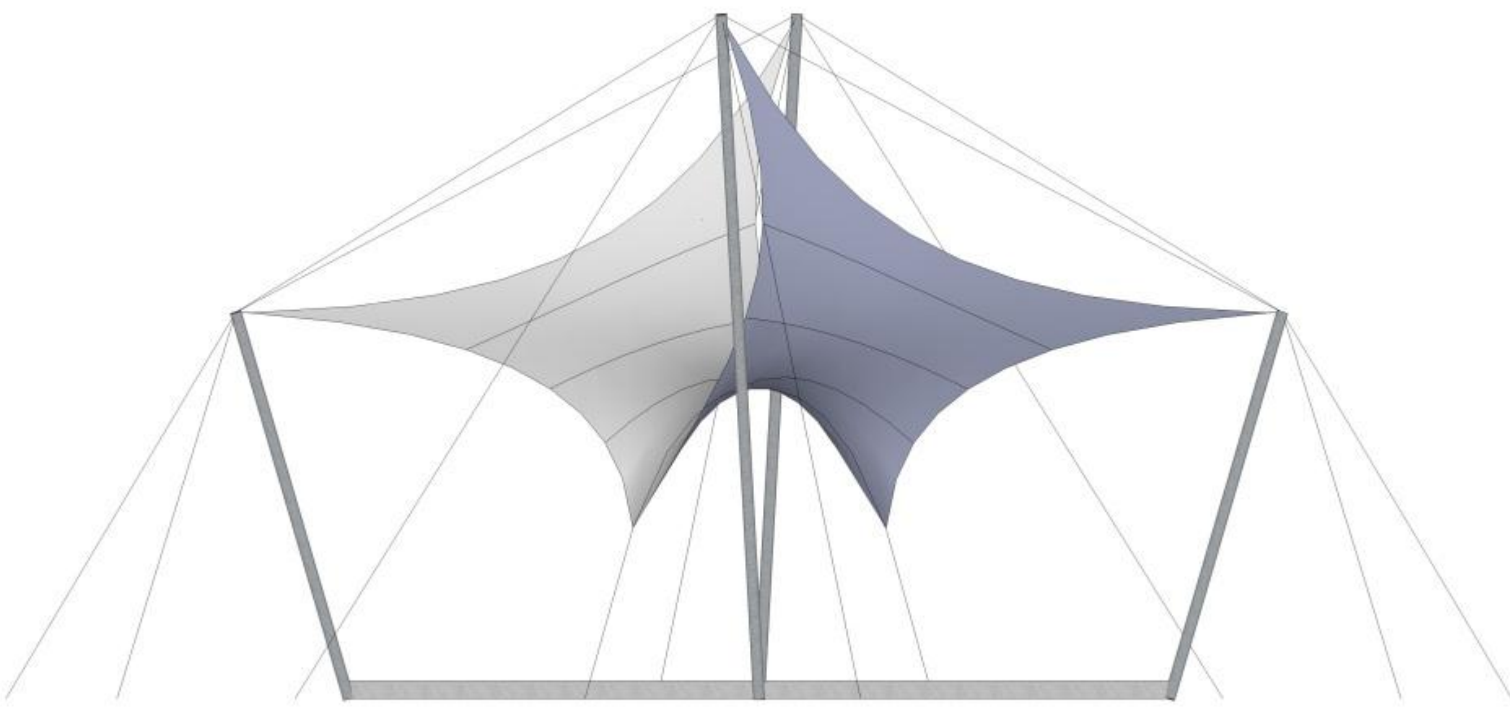


Figure 45: East View

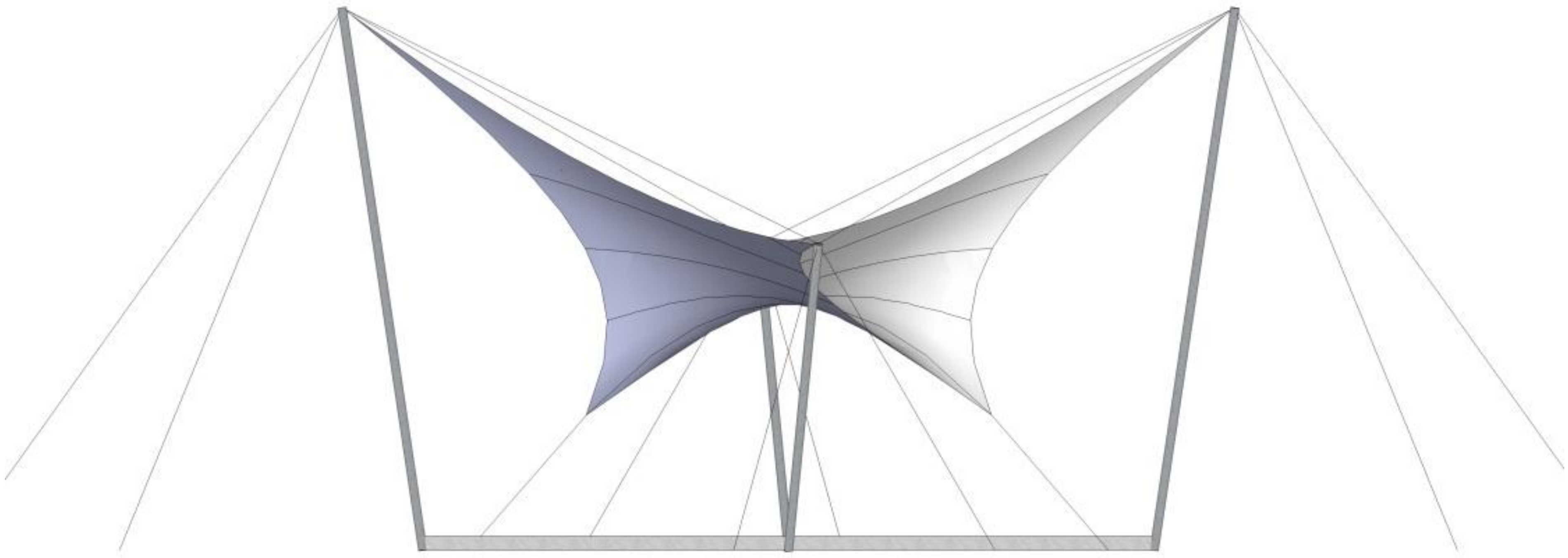


Figure 46: South view

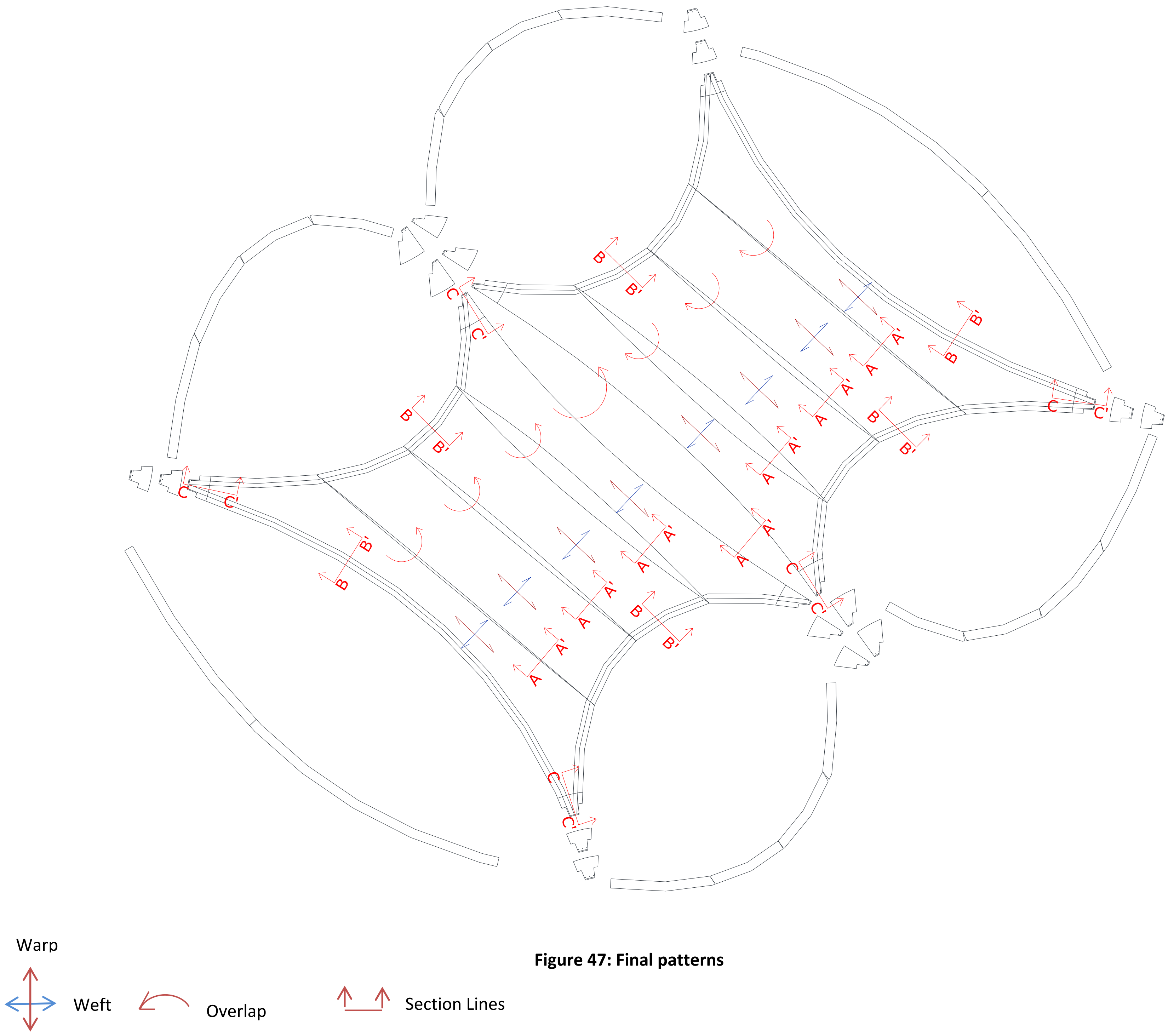
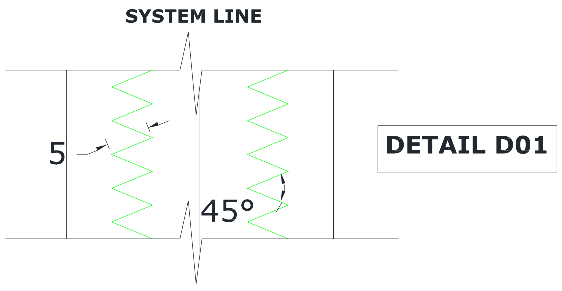


Figure 47: Final patterns

Since Jute 13x13 fabric is not weldable, double backing run stitched seam is introduced. To protect seam from water penetration, water proof UV stabilized polyethylene transparent tape is used to cover seams.



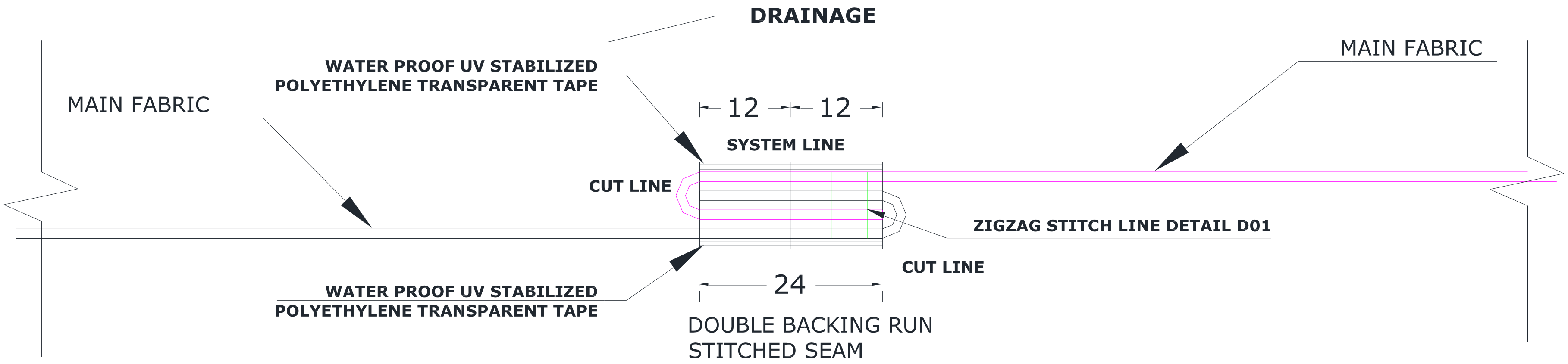


Figure 48: Section AA

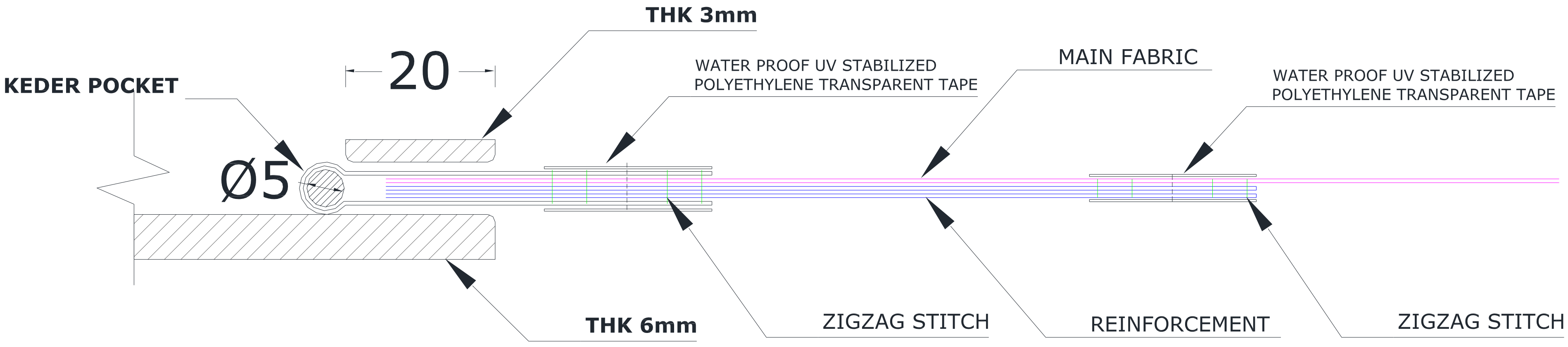


Figure 49: Section CC

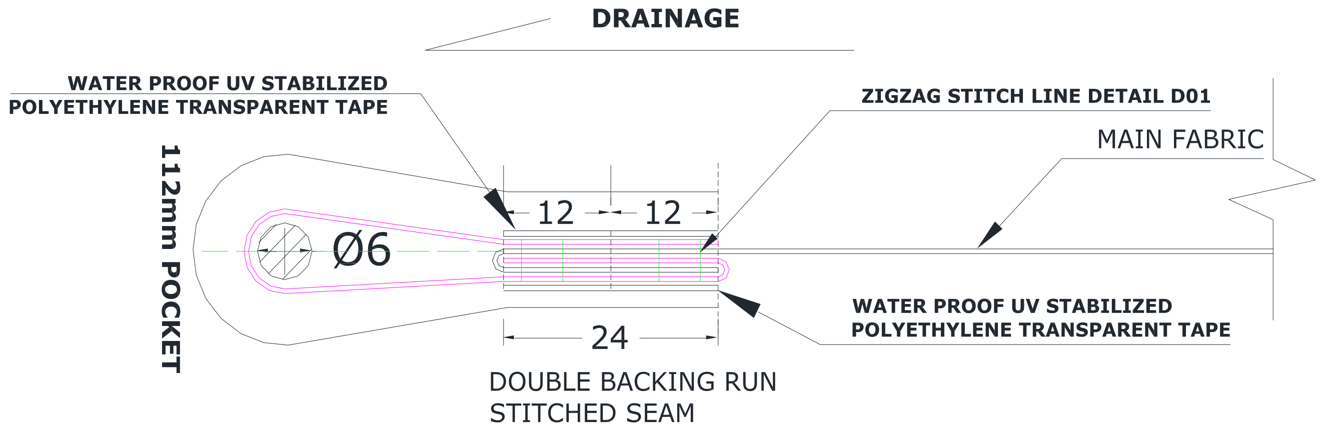


Figure 50: Section BB

Patterns are nested on 1.32m wide Jute 13x13 fabric. Minimisation of the fabric has been considered while nesting

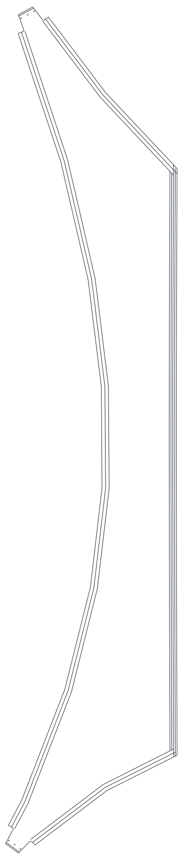


Figure 51: Single pattern

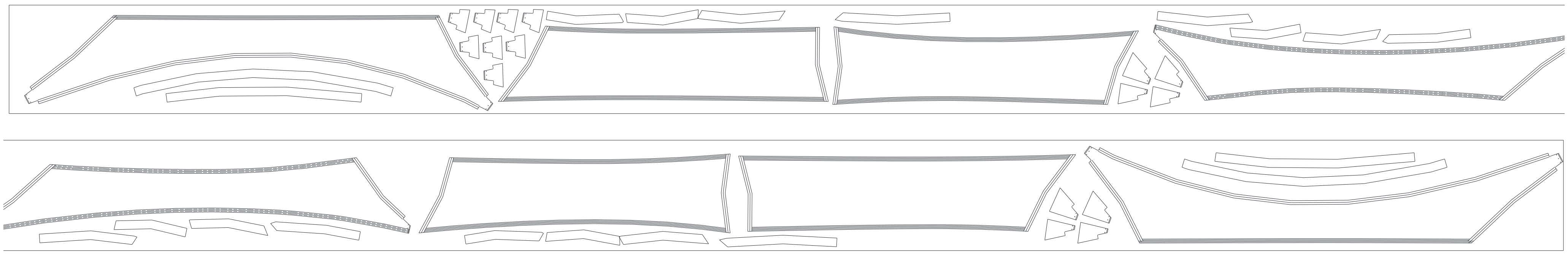


Figure 52: Nesting of the patterns on the Jute 13x13 fabric

4.8 Detail Design

Detail design is an important feature for a membrane structure. Detailing not only helps to flow forces through structural systems easily, but also through detailing beauty and elegance of a structure can be expressed.

4.8.1. Cable dimensioning

Dimensioning of the cables is given below.

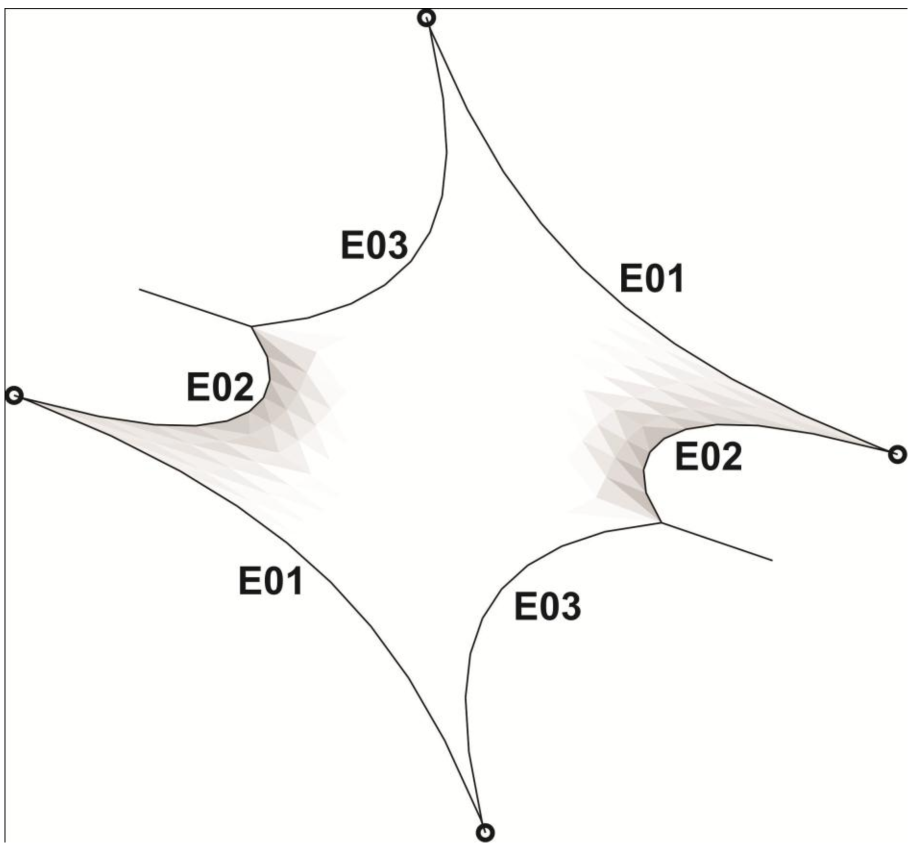


Figure 53: Edge cables

Table 11: Edge Cables

Cable Position	Maximum force F_d kN	Cable Length m	Cable type	Cable diameter mm	Characteristic breaking load F_{uk} kN	Safety factor γ_R	Material Safety Factor γm	Limit Tension F_{Rd} kN
E01	10.153	5.56	PE03	6.1	26	1.1	1.5	15.8
E02	2.901	4.1	PE03	6.1	26	1.1	1.5	15.8
E03	2.127	3.9	PE03	6.1	26	1.1	1.5	15.8

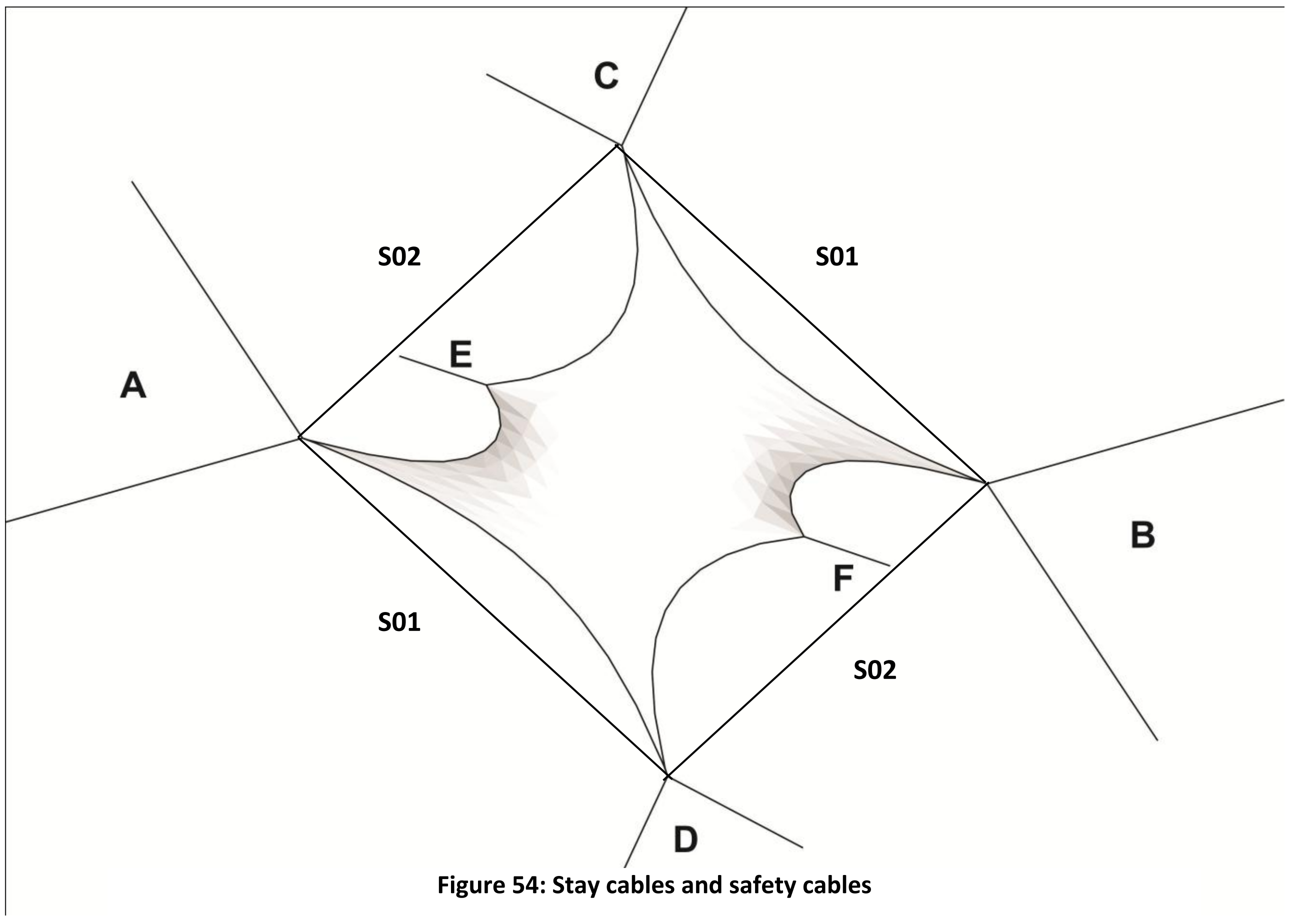


Figure 54: Stay cables and safety cables

Table 12: Stay cables

Cable Position	Maximum force Fd kN	Cable Length m	Cable type	Cable diameter mm	Characteristic breaking load Fuk kN	Safety factor γR	Material Safety Factor γm	Limit Tension FRd kN
A/B	9.8	7.4	PE03	6.1	26	1.1	1.5	15.8
C/D	10.23	4	PE03	6.1	26	1.1	1.5	15.8
E/F	5.23	2	PE03	6.1	26	1.1	1.5	15.8

Length of the safety cable S01 is 7.6m and S02 is 6.7m. Cable type for the safety cables is PE03 and diameter is 6.1mm.

4.8.2. Membrane Corner Design

To transfer forces from cables and tangential forces from doubly curved membrane surface corner plates are designed. Minor adjustment and fine tuning can be done through nut and turnbuckle. There are three types of corner plates CP01, CP02, CP03. Location of these corner plates shown below

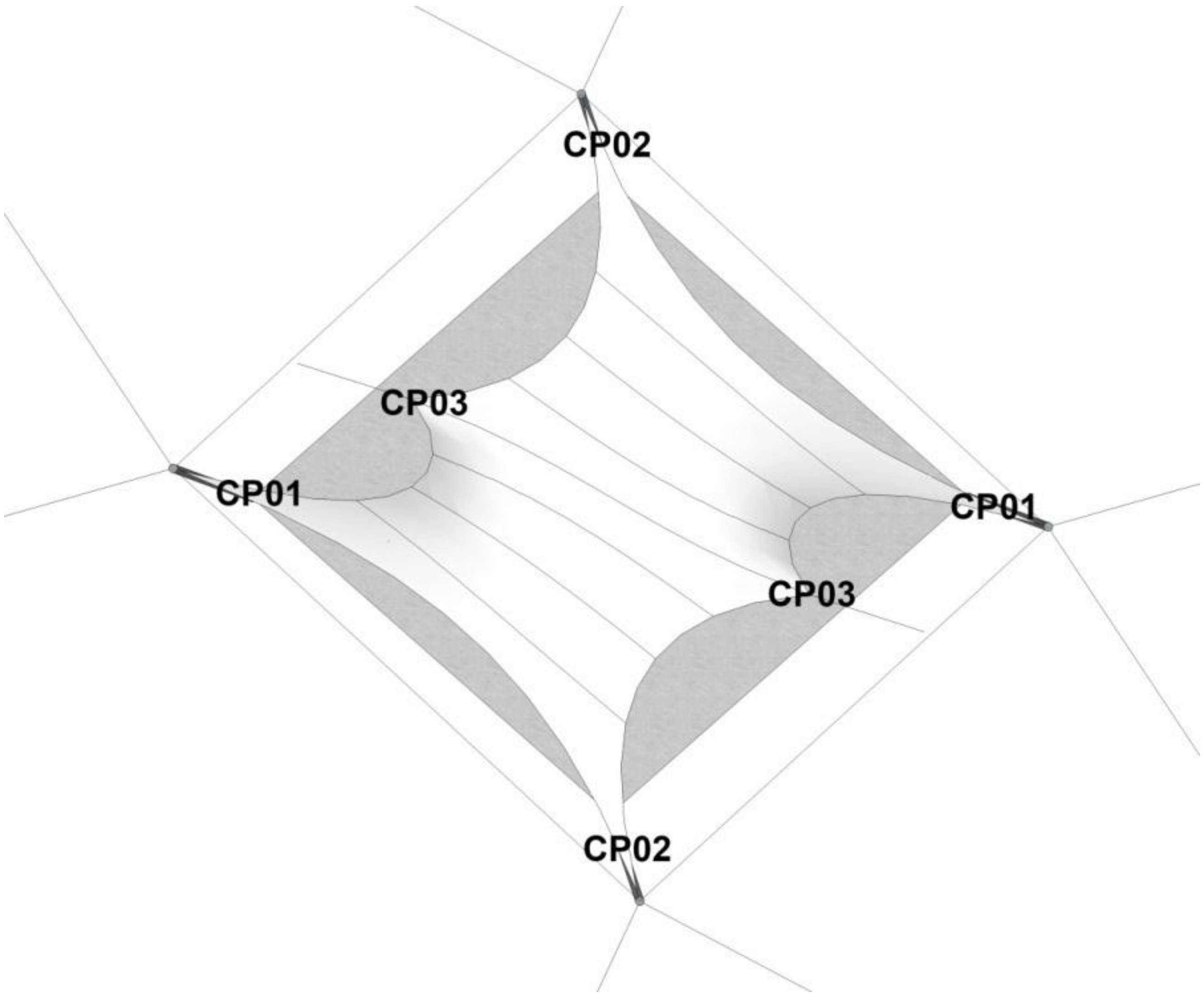


Figure 55: Location of the corner plates

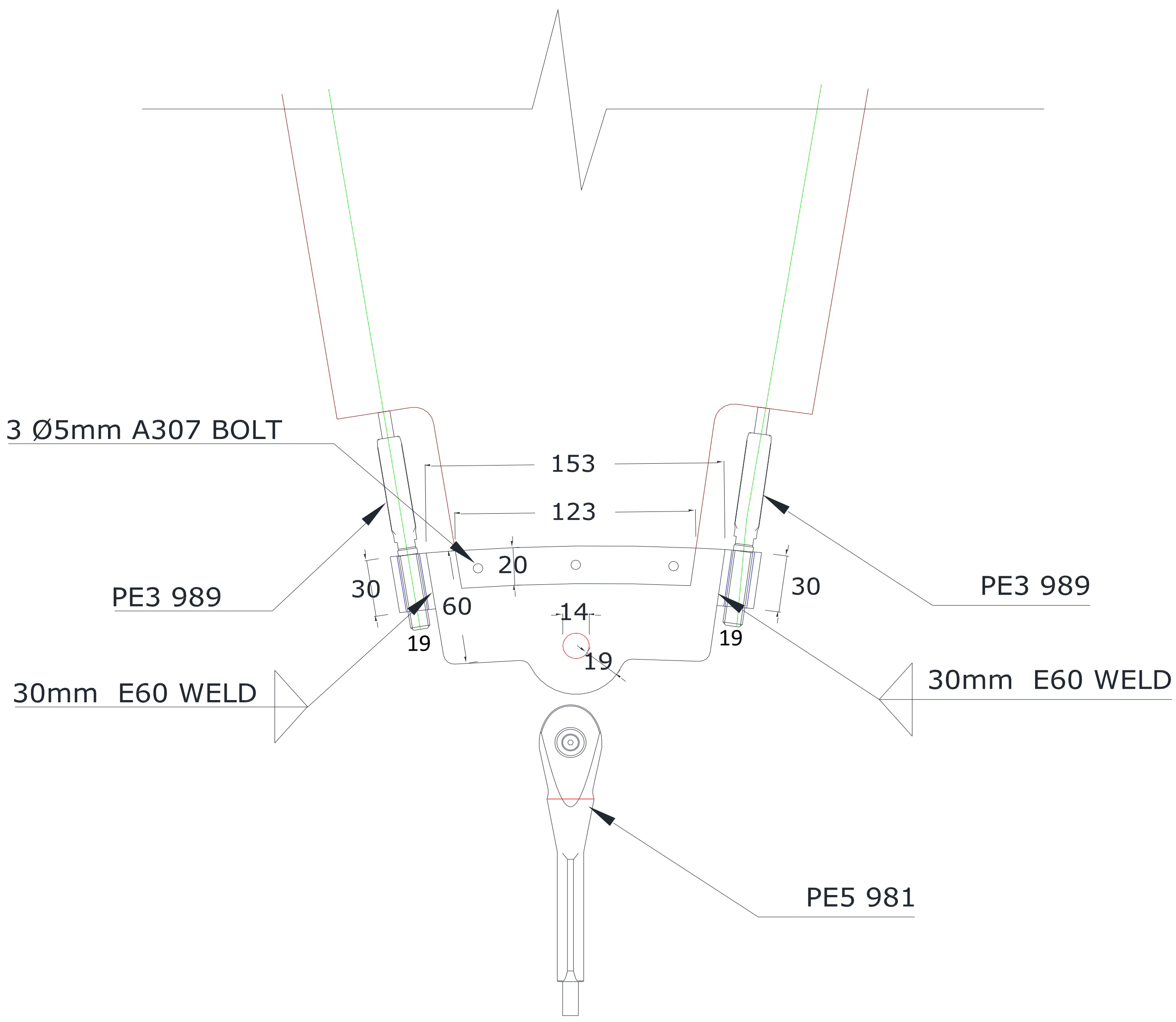


Figure 56: Corner Plate CP01 detail

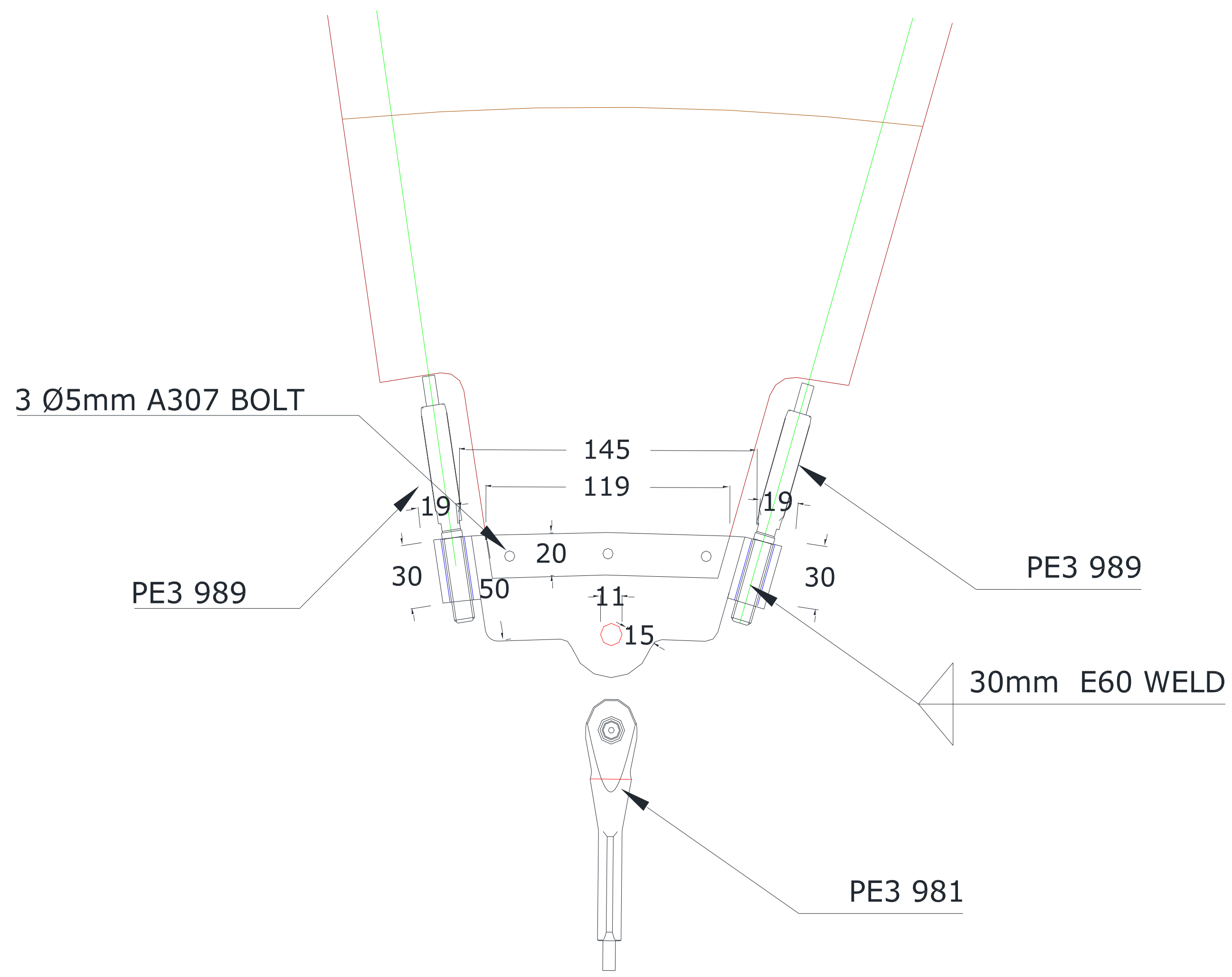


Figure 57: Corner Plate CP02 detail

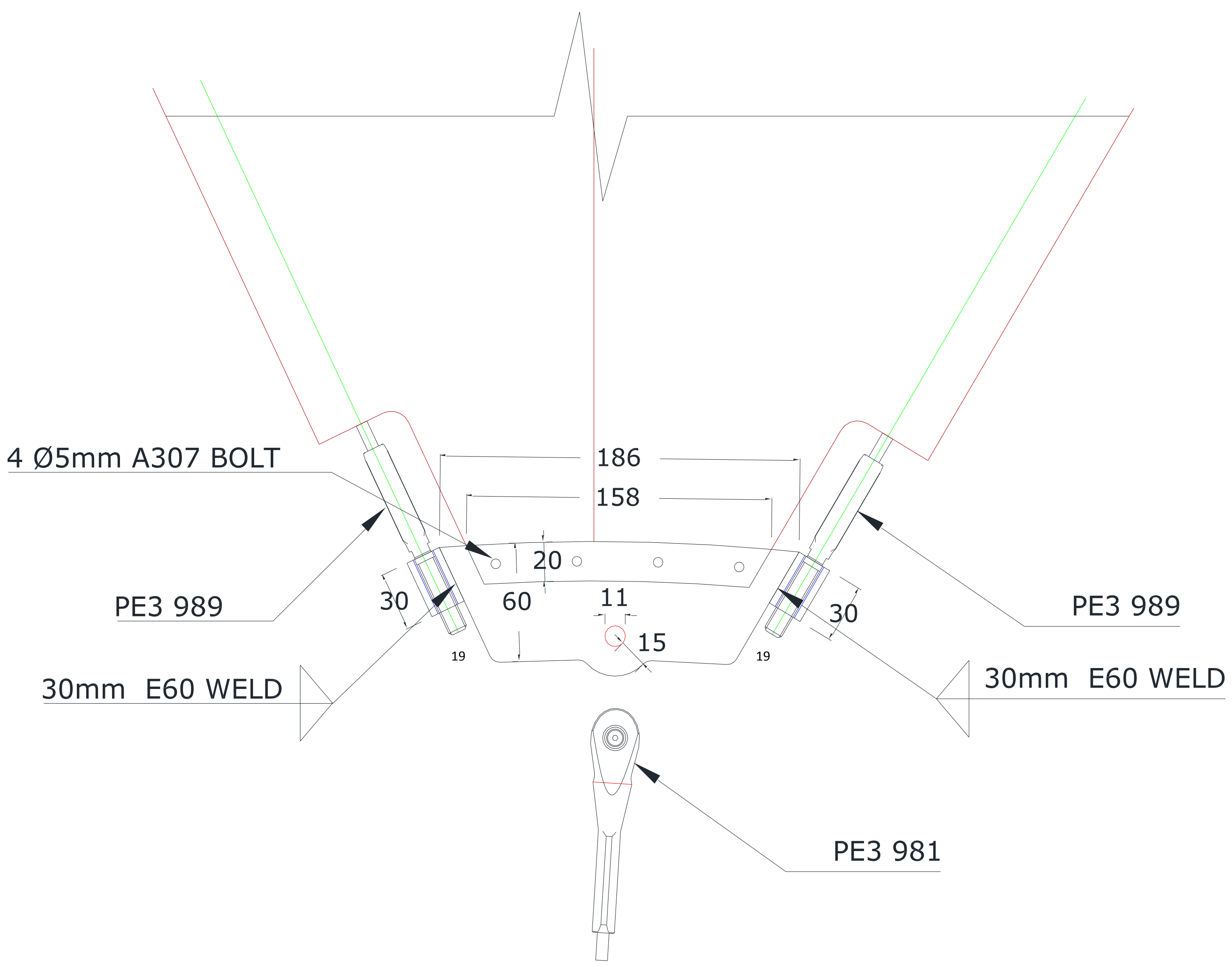


Figure 58: Corner Plate CP03 detail

4.8.3. Connection Design

Connections are designed in a way to facilitate flexibility and displacement of the membrane structure under dynamic conditions. Connections with mast 01 and mast 02 are given below.

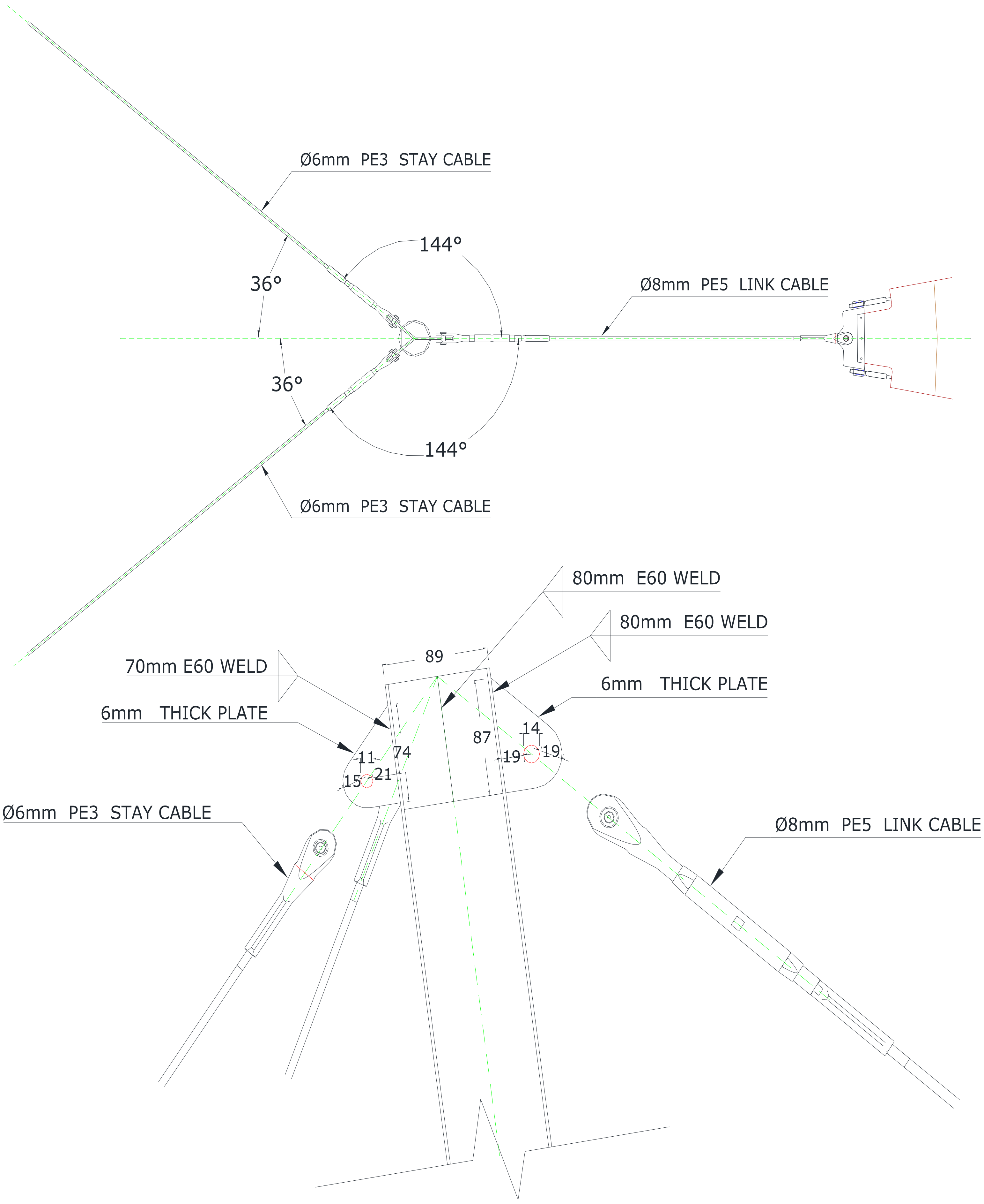
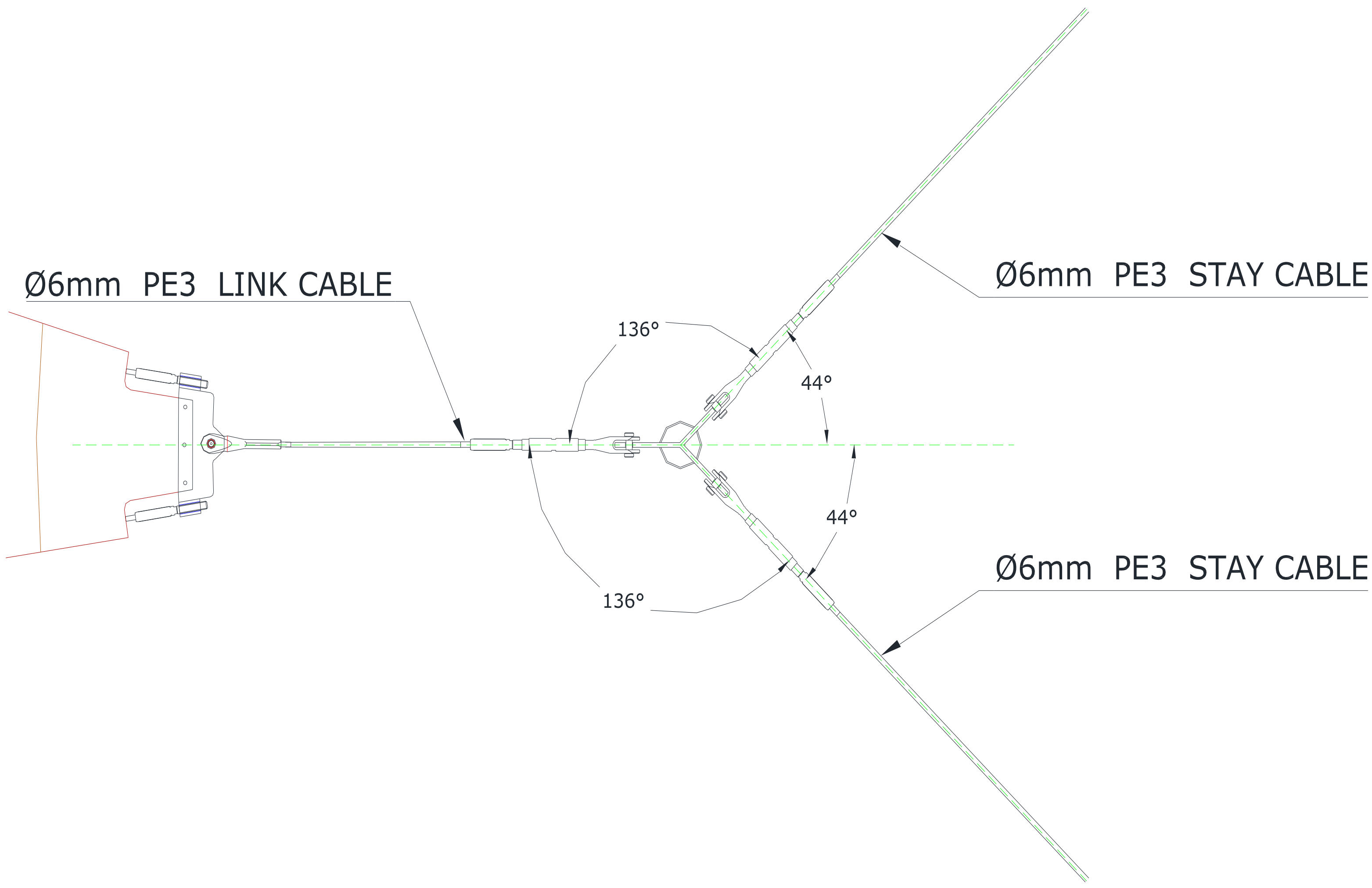


Figure 59: Connection with Mast01



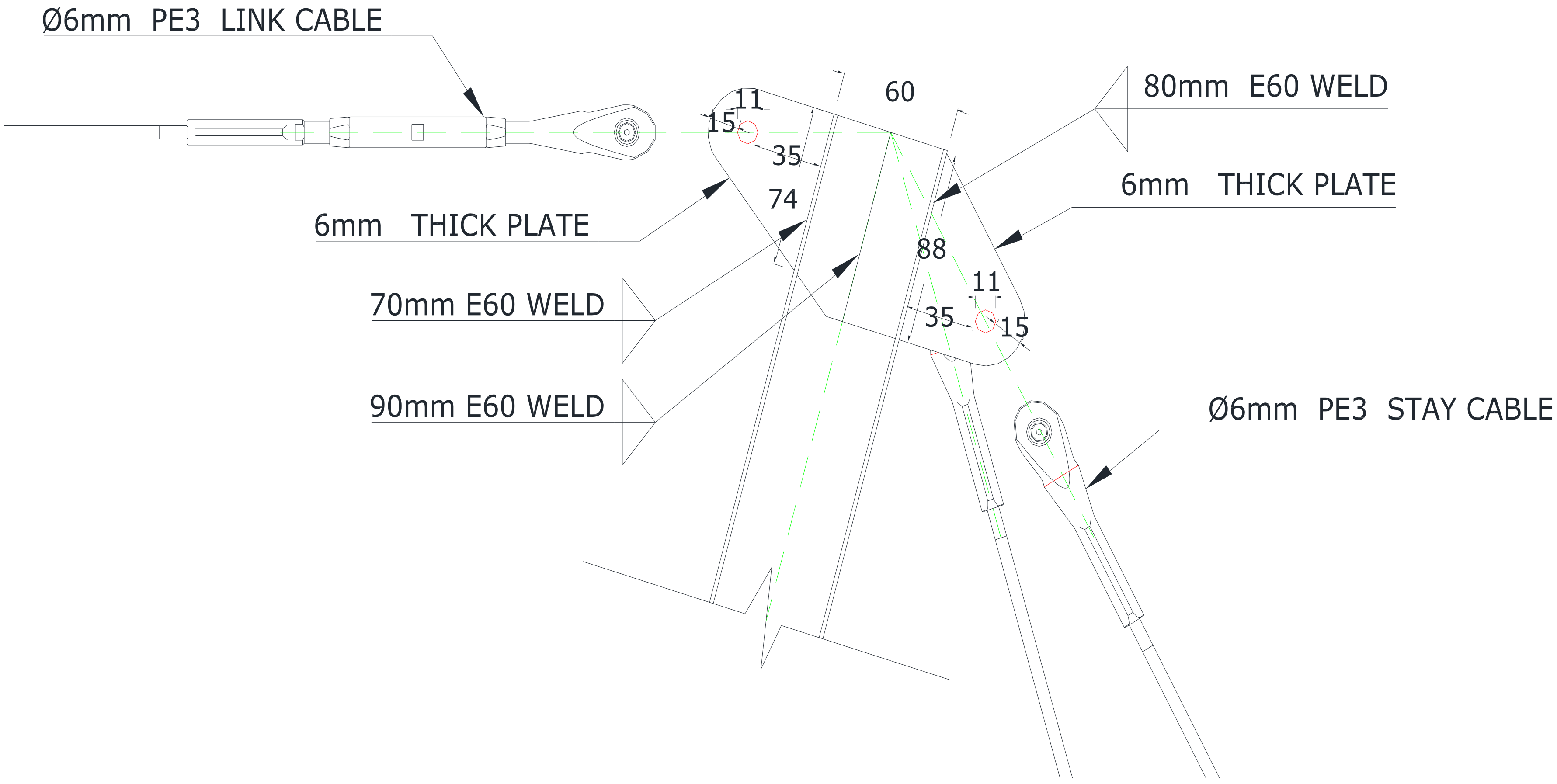


Figure 60: Connection with Mast02

4.8.4. Masts design

Mast has been designed according to AISC/LRFD method. Mast01 and mast02 is made of A36 steel. Mast01 is 5.9m long and 89.1mm in diameter 2.5mm thick. Mast02 is 3.4m long and 60.3mm in diameter 2.0mm thick. Detail calculation has been provided in appendices.

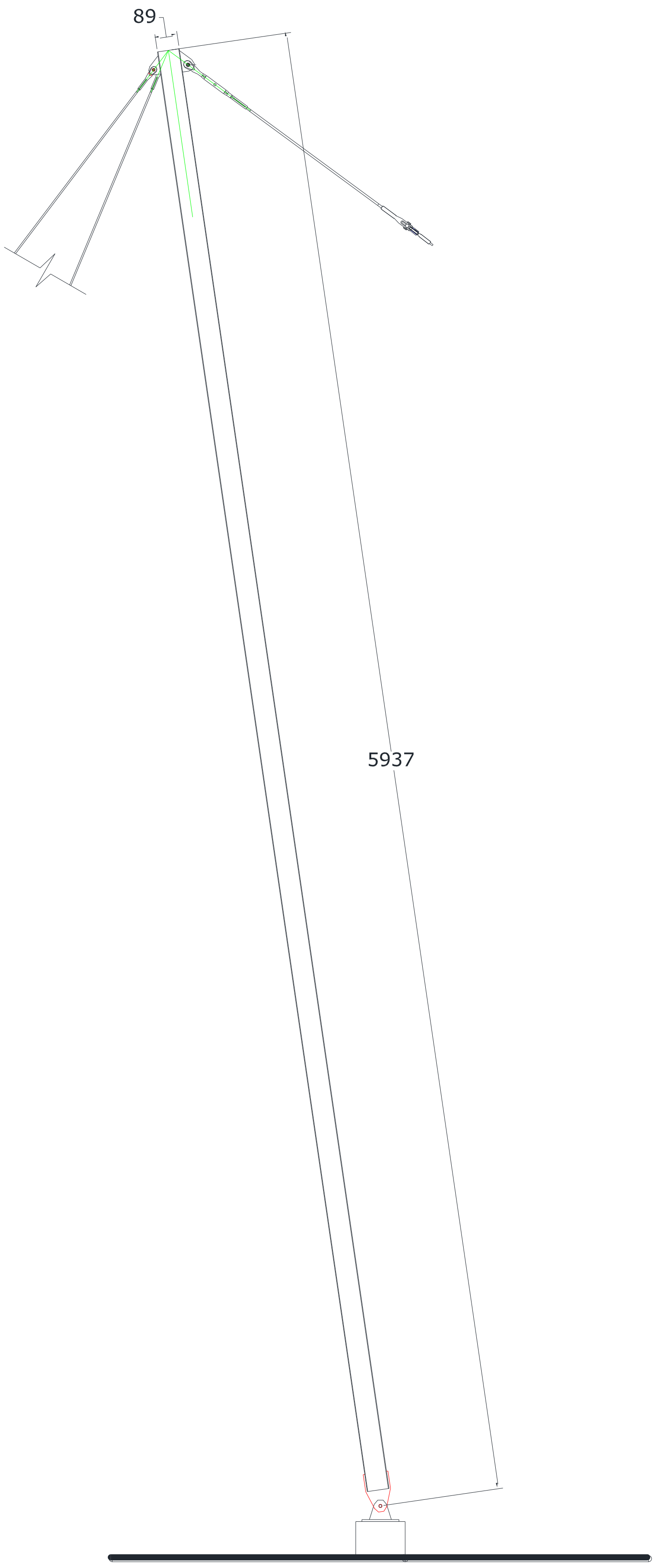


Figure 61: Mast01

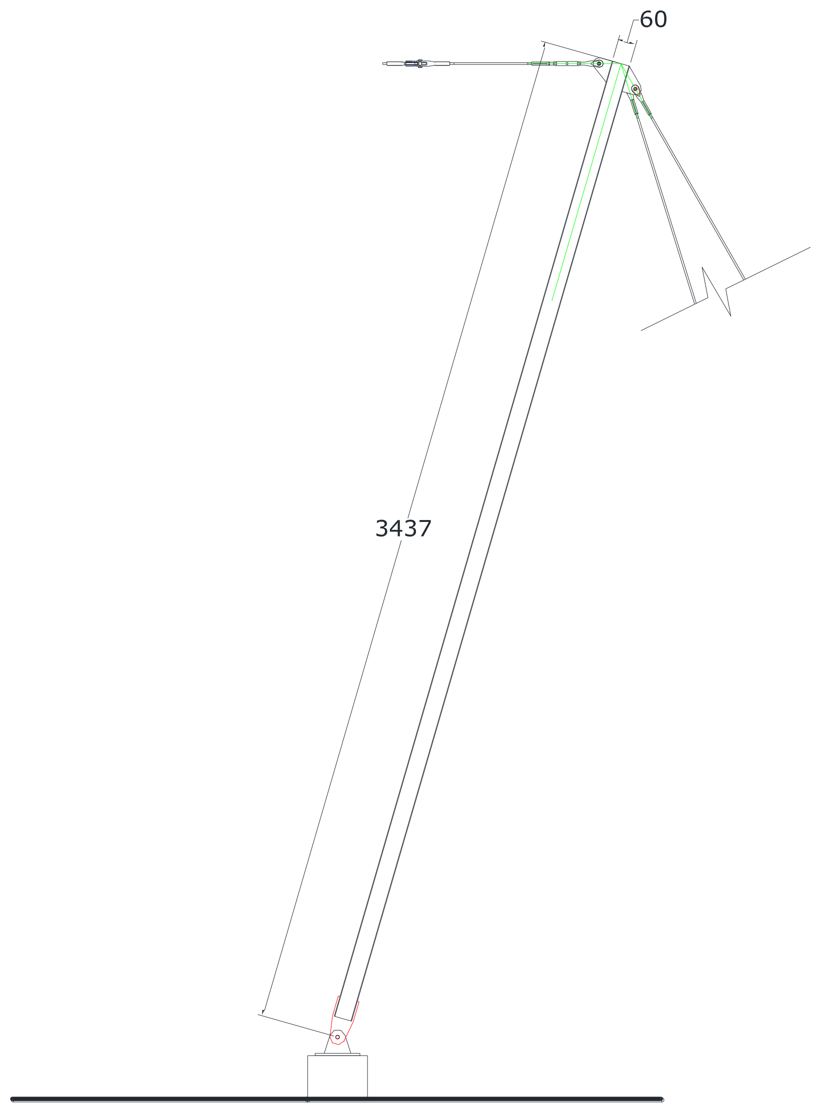


Figure 62: Mast02

4.8.5. Anchorage design

Light foundation is designed to prevent wind uplift and to facilitate connection of masts and stay cables to the ground. Detail of the foundation is provided in appendices.

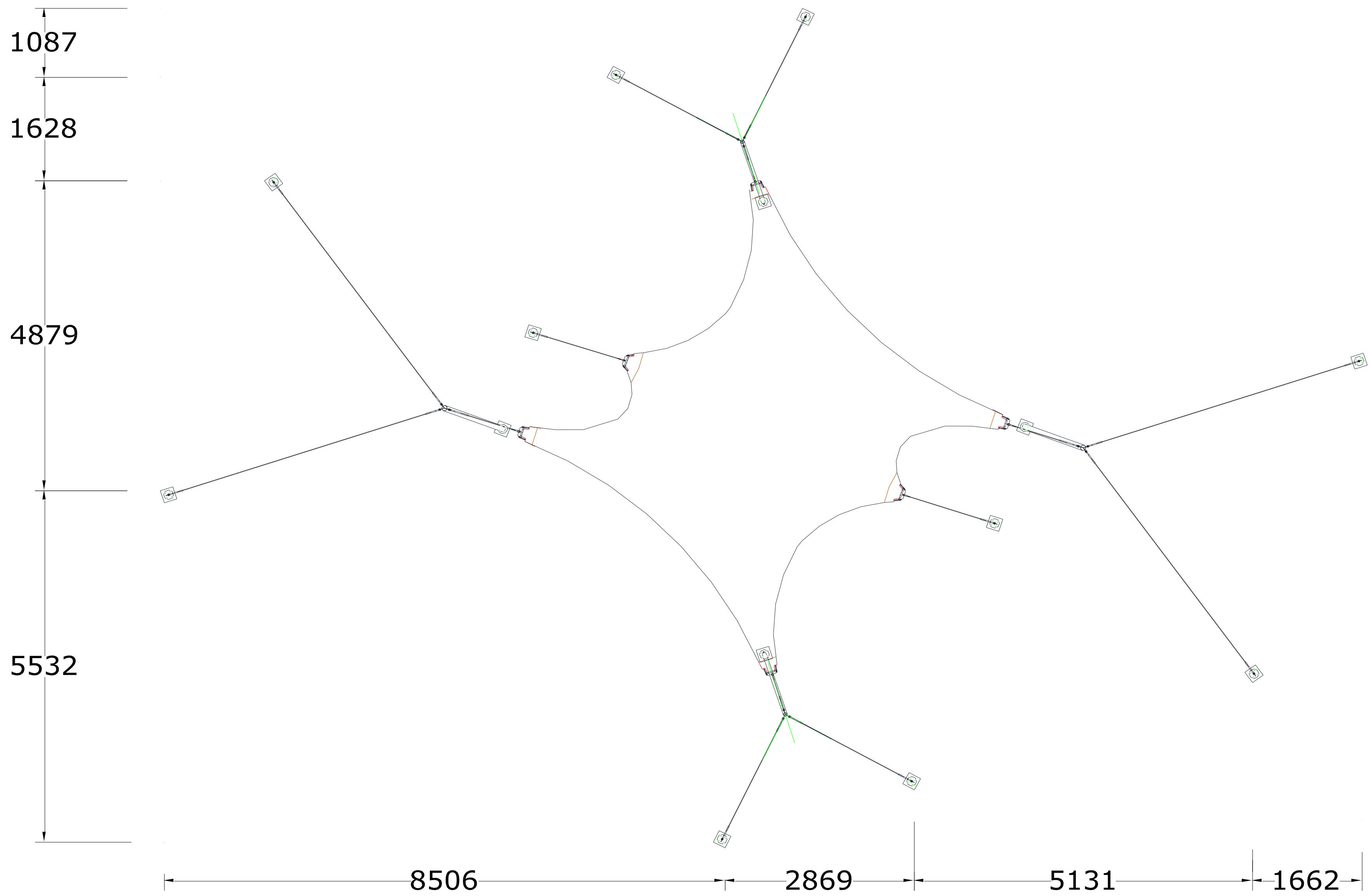


Figure 63: Foundation layout

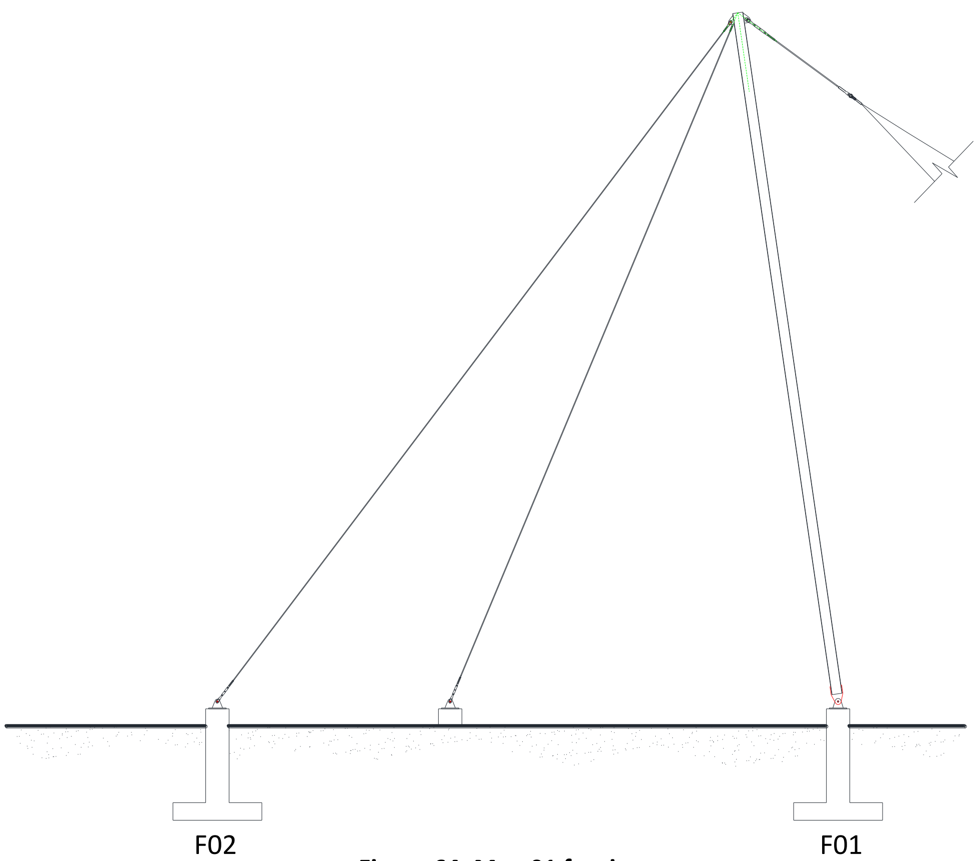


Figure 64: Mast01 footing

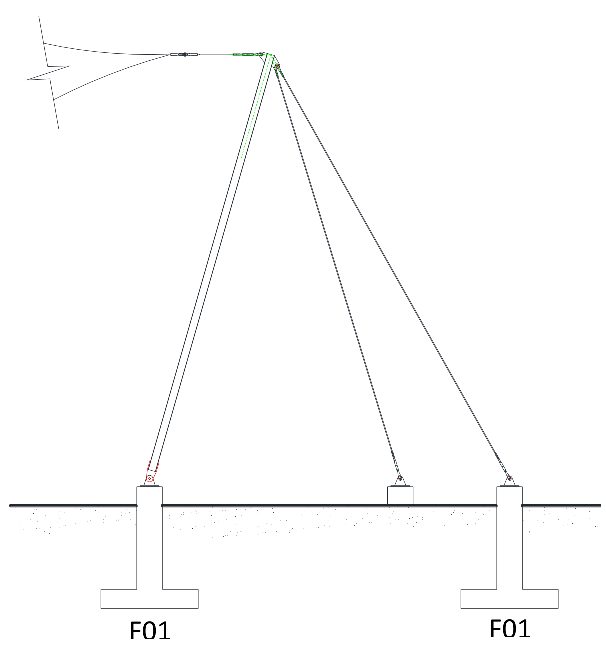


Figure 65: Mast02 footing

Chapter 05:

Fabrication

5.1 Cost Estimation

Estimation of the cost is based on local market price. Estimation is given below.

STATISTICAL VALUES

all values are given to the surface of the construction -x/SUR

Confection M	**cost confection /m²SUR**	**€/m2**	13.60
Steel Weight total **STAHL**		**kg** **kg/m²**	132.00 3.52
Total cost without planning and VAT		**€/m²**	87.61
Overall cost including 10% General Contractor….		**€/m2**	251.42
STATISTICAL VALUE PLANNING	**Planning /m2**	**€/m2** **%**	26.28 30

Statistical Values in % of the Membrane Project

without approval cost and On site tasks

total Sum in € **7071 €**

1.	**MEMBRANE**	510	€	**7.21%**
2.	**STEEL**	697	€	**9.86%**
3.	**CABLES**	1,383	€	**19.56%**
4.	**TRANSPORT**	300	€	**4.24%**
5.	**FOUNDATION**	2,800	€	**39.6%**
6.	**ERECTION**	395	€	**5.6%**
7.	**PLANNING COST ENGINEERING**	985.61	€	**14%**

From the statistical values of cost calculation, it can be seen that because of using Jute fabric cost of membrane is only around 7.21%. Around 50% of the cost is spent on transportation, foundation and erection process. Cost of steel masts and cables are around 30%. Consultation and planning will cost 14%.

5.2 Time Schedule

The purpose of time schedule is to reduce time wastage as well as enhance work efficiency. It clarifies working steps and links different steps until completion of a project. The time schedule for the membrane cover for visitor shed in Dhaka zoo comprises 19 steps from concept preparation to handover. Approximately 12 weeks will require upto the handover of the project.

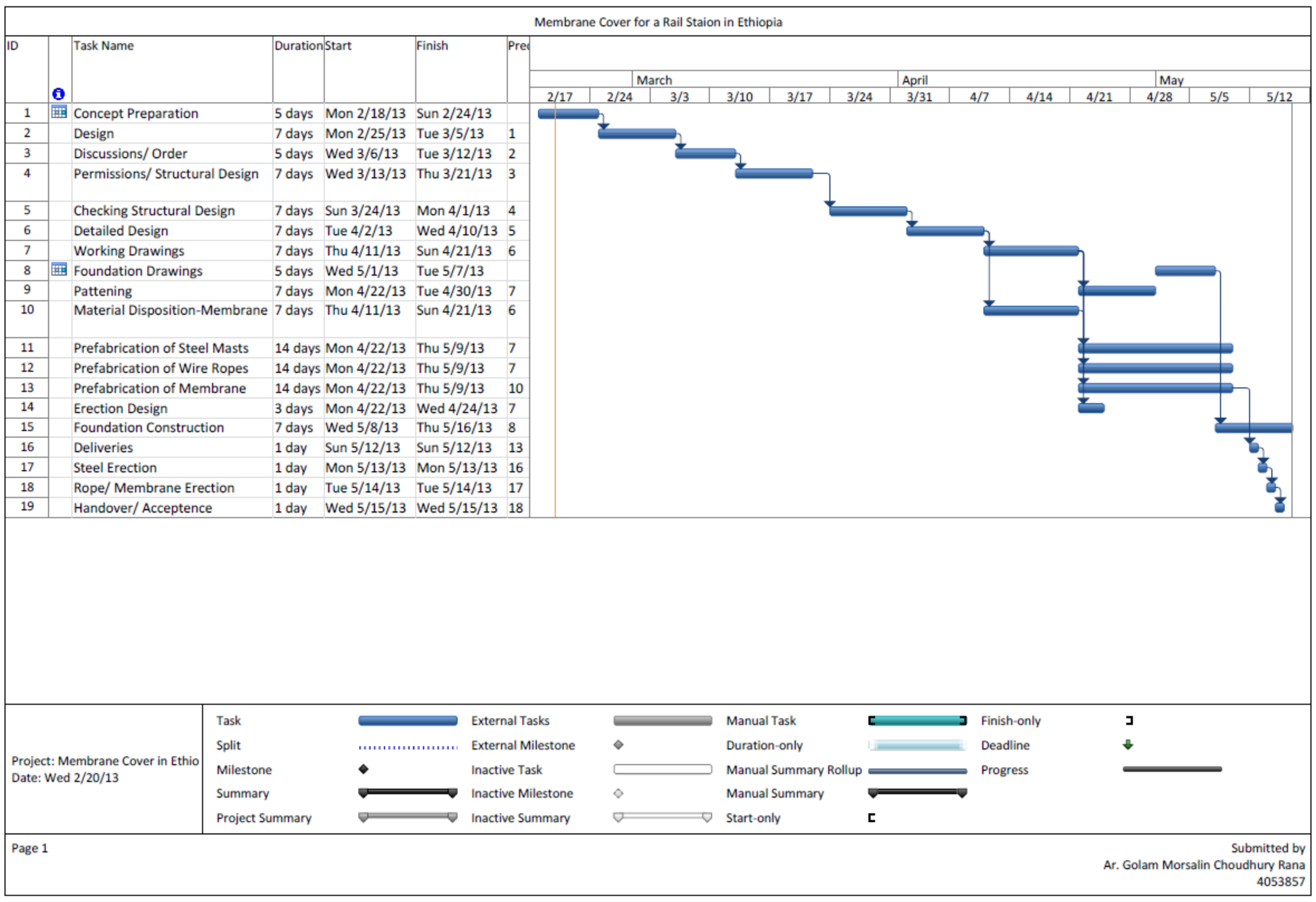


Figure 66: Time schedule

5.3 Erection procedure

Erection process consists of different activities it include unloading of the material, site set-up, erection preparation, preassembly, lifting, hanging and preassembly[1].

Erection procedure will follow three steps. First step begins with setting up the membrane with masts and insertion of edge cables into the pockets. The unpacked membrane laid-out on ground, cables are slid in pockets and then corner plates are assembled at the corners. Masts are connected with base plates through pins and then stay cables as well as corner plates are connected with it. The membrane structure is then ready to be erected.

In second steps the membrane structure is erected pivoting the masts at the base one by one with the help of three men. Then stay ropes are then connected with the anchorage plates and masts. Mechanical griphoist will be used to connect and to provide sufficient tension in stay cables.

In step three minor adjustment and rigging are done. For that purpose lightweight scaffolds made of bamboo will be used. Fine tuning of the membrane is achieved through rigging edge cables.

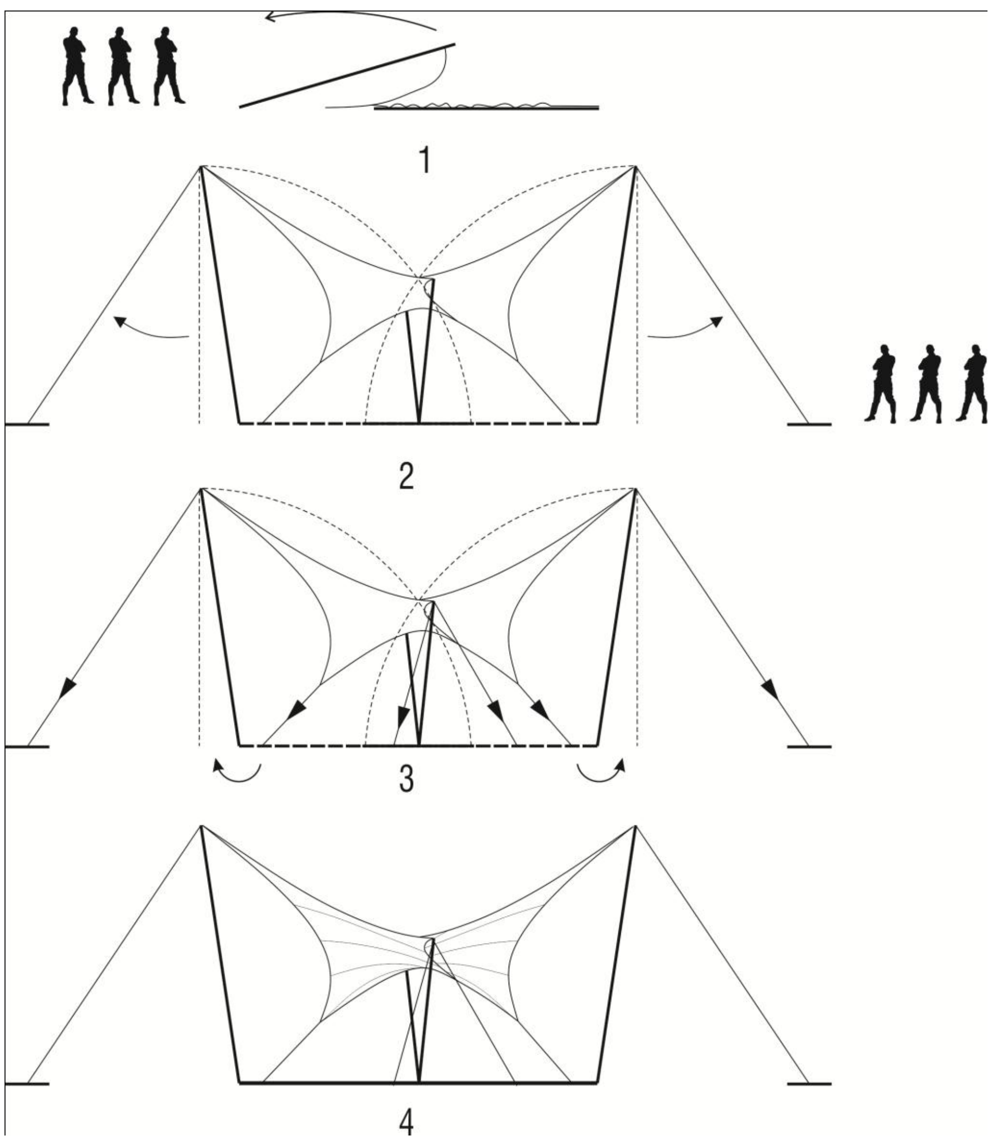


Figure 67: Erection steps for membrane cover

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Chapter 06: Conclusion

In conclusion it can be deduced from previous chapters that one side laminated Jute fabric which is available in the market can be used as membrane cover for visitor shed design, it is the main objective of this study. Jute 13x13 fabric has highest tensile strength. It can withstand wind loads of Dhaka. Though both side laminated Jute fabric is not currently available in market, but it can be ordered from BJRI for large quantities, which is more suitable for Jute as Polypropylene lamination will protect it from humid climate of Dhaka.

The great advantage of this material is that it is cheaper, readily available and environment friendly. But major disadvantage is its durability and relatively weaker strength than conventional fabrics. Further study should be done to make Jute fabric weather proof, durable and higher tensile strength.

Jute fabric may open up as a new potential environment friendly green fabric for tensile membrane structures and it eventually can contribute in economic growth of Bangladesh.

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List of Figures and Tables

Appendices

Appendix 01: Tensile Strength Lab Test Results

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DEPARTMENT OF CIVIL ENGINEERING

Mobile: 01819 557964; PABX: 966 5650-80 Ext. 7226

BRTC Bureau of Research, Testing & Consultation

GEOTECHNICAL ENGINEERING LABORATORY

TESTING OF LAMINATED JUTE TEXTILE *Page: 1/2*

BRTC No: 110035364/ CE/ 12-13 Date: 06/11/12 *Specimen ID: BRTC35364(LG)*

Sent by: Mr. Golam Mursalin Chowdhury *Colour: Brown*

85/A R.K. Mission Road, Dhaka-1203

Reference: Letter Date: 06/11/12

Project: -

Date of Test: 07/11/12 Test Method: ASTM/ DIN

TEST RESULTS

Test Parameter	Direction	Test Standard	Unit	Test Result
Average Mass per unit Area	--	ASTM D5261	gm/m^2	376
Average Thickness (under a Pressure of 2 kPa)	--	ASTM D5199	mm	--
Apparent/ Effective Opening Size	--	ASTM D4751$^+$	micron	--
Average Horizontal Permeability at 20 °C	--	ASTM D4716/DIN	x10^{-3} m/sec	--
Average Vertical Permeability at 20 °C	--	DIN	x10^{-3} m/sec	--
Average Permitivity at 20 °C	--	ASTM D4491	x 10^{-2}/ sec	--
Average Grab Tensile Strength °C (RT)	MD/ Direction X*	ASTM D4632	N	--
	XMD/ Direction Y*		N	--
Average Grab Tensile Elongation °C (RT)	MD/ Direction X*		%	--
	XMD/ Direction Y*		%	--
Average Strip Tensile Strength at 20 °C (RT)	MD/ Direction X*	ASTM D4595	kN/m	15.4
	XMD/ Direction Y*		kN/m	16.7
Average Strip Tensile Elongation at 20 °C (RT)	MD/ Direction X*		%	10
	XMD/ Direction Y*		%	10
Avg. CBR Puncture Resistance °C (RT)	--	ASTM D6241	N	--
Average Size of Bag at 20 °C (RT)	--	--	--	1150 x 798
Average Seam Strength at 20 °C (RT)	--	ASTM D4884	N	--

+ Sand fractions were used in place of glass beads. RT = Room Temperature

* Machine Direction (MD) and Cross Machine Direction (XMD) were not identifiable. Instead, arbitrarily X and Y directions were chosen

Samples were received in unsealed condition

Countersigned by:

Dr. Md. Abdur Rouf
Professor, Civil Engg. Dept.

DEPARTMENT OF CIVIL ENGINEERING * BUET *

Test Performed by:

14.11.12

Dr. Md. Zoynul Abedin
Professor, Civil Engg. Dept.

Important Notes:

Samples as supplied to us have been tested in our laboratory. As such, BRTC does not have any responsibility as to the representativeness the samples required to be tested. It is recommended that samples are sent in a secured cover/ packet/ container duly sealed and signed by competent authority. In order to avoid fradulent fabrication of test results, it is recommended that the test reports be collected by an authorized person, and not by the contractor/ Supplier.

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)
DEPARTMENT OF CIVIL ENGINEERING
Mobile: 01819 557 964; PABX: 966 5650-80 Ext. 7226; www.buet.ac.bd/ce/
BRTC Bureau of Research, Testing & Consultation
GEOTECHNICAL ENGINEERING LABORATORY

BRTC No. : 110036775/CE/12-13 Dated 04/12/2012
Sent by : Mr. A. Golam Mosalin Choudhury Rana
MIAB
85/A, R.K. Mission Road
Dhaka-1203
Your Ref. : Letter of dated 4/12/2012
Sample : Laminated Jute Fabric
Colour : Brown
Sample seal condition : Unsealed

TEST RESULTS ON LAMINATED JUTE FABRIC

Parameter	Test Standard	Unit	Test Result
Mass per Unit Area	ASTM D3776	gm/m^2	331
Wide Width (Strip) Tensile Strength at 20°C	ASTM D4595	kN/m	14/12
Wide Width (Strip) Tensile Elongation at 20°C	ASTM D4595	%	12/8

Note: Where two values are provided, they refer to two perpendicular directions

DEPARTMENT OF CIVIL ENGINEERING * BUET

Countersigned by:

Test performed by:
11/12/12

Dr. Abu Siddique
Professor
Department of Civil Engineering
Bangladesh University of Engineering and Technology, Dhaka, Bangladesh

BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY (BUET)

DEPARTMENT OF CIVIL ENGINEERING

Mobile: 01819 557964; PABX: 966 5650-80 Ext. 7226

BRTC Bureau of Research, Testing & Consultation

GEOTECHNICAL ENGINEERING LABORATORY

TESTING OF JUTE COTTON BLEND TEXTILE ***Page: 2/2***

BRTC No: 110035364/ CE/ 12-13 Date: 06/11/12 *Specimen ID: BRTC35364(LG)*

Sent by: Mr. Golam Mursalin Chowdhury *Colour: Brown*

85/A R.K. Mission Road, Dhaka-1203

Reference: Letter Date: 06/11/12

Project: -

Date of Test: 07/11/12 Test Method: ASTM/ DIN

TEST RESULTS

Test Parameter	Direction	Test Standard	Unit	Test Result
Average Mass per unit Area	--	ASTM D5261	gm/m^2	2213
Average Thickness (under a Pressure of 2 kPa)	--	ASTM D5199	mm	--
Apparent/ Effective Opening Size	--	ASTM D4751$^+$	micron	--
Average Horizontal Permeability at 20 °C	--	ASTM D4716/DIN	x10^{-3} m/sec	--
Average Vertical Permeability at 20 °C	--	DIN	x10^{-3} m/sec	--
Average Permitivity at 20 °C	--	ASTM D4491	x 10^{-2}/ sec	--
Average Grab Tensile Strength °C (RT)	MD/ Direction X*	ASTM D4632	N	--
	XMD/ Direction Y*		N	--
Average Grab Tensile Elongation °C (RT)	MD/ Direction X*		%	--
	XMD/ Direction Y*		%	--
Average Strip Tensile Strength at 20 °C (RT)	MD/ Direction X*	ASTM D4595	kN/m	18.1
	XMD/ Direction Y*		kN/m	15.2
Average Strip Tensile Elongation at 20 °C (RT)	MD/ Direction X*		%	4
	XMD/ Direction Y*		%	22
Avg. CBR Puncture Resistance °C (RT)	--	ASTM D6241	N	--
Average Size of Bag at 20 °C (RT)	--	--	--	1150 x 798
Average Seam Strength at 20 °C (RT)	--	ASTM D4884	N	--

+ Sand fractions were used in place of glass beads. RT = Room Temperature

* Machine Direction (MD) and Cross Machine Dirrection (XMD) were not identifiable. Instead, arbitrarily X and Y directions were chosen

Samples were received in unsealed condition

Countersigned by:

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Test Performed by:

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Appendix 02: Cost Estimation

Target price calculation for

1. MEMBRANE

Type Jute 13x13

			check		
covered floor are	m²	25.00			
surface factor		FACTOR	**1.50**		
Surface (SUR)	m²	25.00	**37.50**		
wastage factor		FACTOR	**1.60**		
	m²		**60.00**		
additional consumption	m²		**25**		
total consumption	m²		**85.00**		
Sales Price Material			**85€**	**1.00**	**Mat Preis€/m2**
confection price	m²	85.00	**425€**	**5.00**	**Conf €/m²**

Cost Membrane PVC MEMBRANE	**total€**	**510**

2. STEEL

2.1 Fittings/ small parts	pieces		€ total	kg total	kg/piece	€/kg
membrane corners	6		54.00	9.00	1.50	6.00
SUBTOTAL FITTINGS		**€**	**54.00**			

2.2 MASTS (High Point) galvanised	pieces	length/piece		€ total	kg total	kg/m	€/kg
diameter 89 mm	2	6.00		300.00	60.00	5.00	5.00
diameter 60 mm	2	3.50		175.00	35.00	5.00	5.00
SUBTOTAL MASTS (High Point)			**€**	**475.00**			

2.3 STEEL FITTINGS	pieces		€ total	kg total	kg/piece	€/kg
for masts-footing-cable plates	14		168.36	28.00	2.00	6.01
SUBTOTAL GENERAL STEEL FITTINGS		**€**	**168.36**			

TOTAL STEEL	**TOTAL €**	**697**

3. CABLES

3.1 MEMBRANE EDGE CABLES	Piece	length/piece	€ total	m	€/m
diameter 6.1mm	2	5.60	56.00	11.20	5.00
	4	4.20	84.00	16.80	5.00
	Piece	x2	€ total	Piece	€/Piece
thread fitting for 6.1 mm	6	12.00	240	12.00	20
SUBTOTAL MEMBRANE EDGE CABLES		**€**	**380**		

3.2 STAY CABLES	pieces	m/piece	€ total	m	€/m
diameter 6.1 mm	4	7.40	148.00	29.60	5.00
	4	4.00	80.00	16.00	5.00
	2	2.00	20.00	4.00	5.00
	pieces	x2	€ total	piece	€/piece
thread fitting for 6.1 mm	10	20.00	400	20.00	20
SUBTOTAL STAY CABLES		**€**	**648**		

3.3 LINK CABLES	pieces	m/piece	€total	m	€/m
diameter 6.1 mm	2	1.00	10.00	2.00	5.00
diameter 8.1 mm	2	0.55	5.50	1.10	5.00
	pieces	x2	€ total	Piece	€/Piece
thread fitting for 6.1 mm	2	4.00	80	4.00	20
thread fitting for 8.1mm	2	4.00	100	4.00	25
SUBTOTAL LINK CABLES		**€**	**110**		

3.4 SAFETY CABLES	pieces	m/piece	€total	m	€/m
diameter 6.1 mm	2	8.50	85.00	17.00	5.00
	2	7.50	75.00	15.00	5.00
	pieces	x2	€ total	Piece	€/Piece
thread fitting for 6.1 mm	4	8.00	160	8.00	20
SUBTOTALSAFETY CABLES		**€**	**245**		

TOTAL CABLES	**total €**	**1,383**
WHOLE 1-3 SUBTOTAL	**€**	**2,590**

4	**TRANSPORT**				
4.1	WEIGHT	kg			
		€/kg			
4.2	VOLUME	m³			
		€/m³			
4.3	PACKING	€			
	SUBTOTAL TRANSPORT	**€**	lump sum		**300**

5	**ERECTION**						
5.1	man-days	Working days	Mann	man-days	**€/day**		
	1worker/1day	3	3	**9.00**	20.00		
					€ total	**180.00**	
5.2	TRAVEL		3	€/travel	5.00		
					€ total	**15.00**	
5.3	Scaffolding			€ total	*on site*	**200.00**	
	SUBTOTAL ERECTION			**€**		**395.00**	

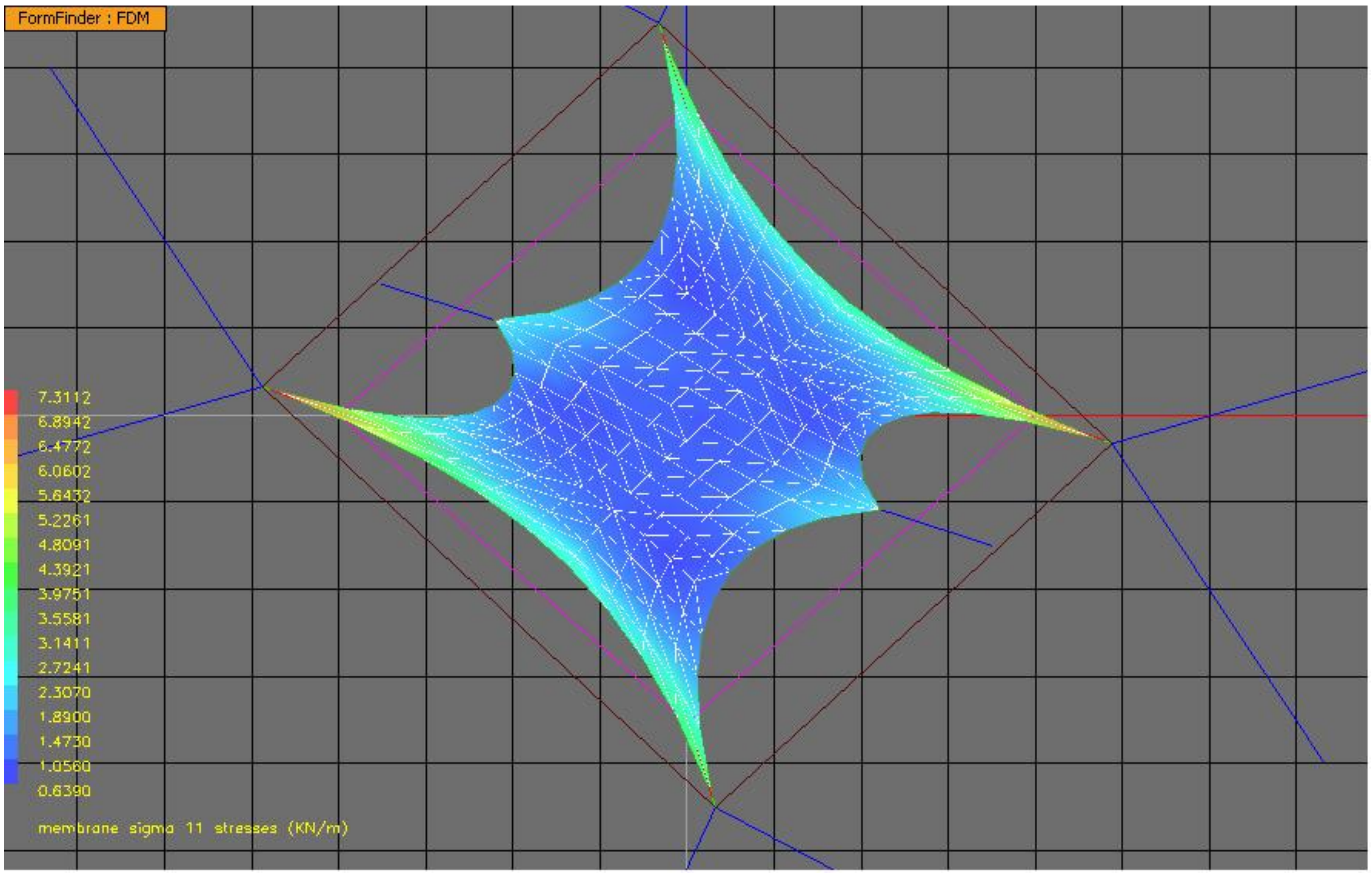
6 FOUNDATION			Unit price		
Amount	7	m³	400.00	€/m³	2,800.00
FOUNDATION TOTAL					**2,800.00**

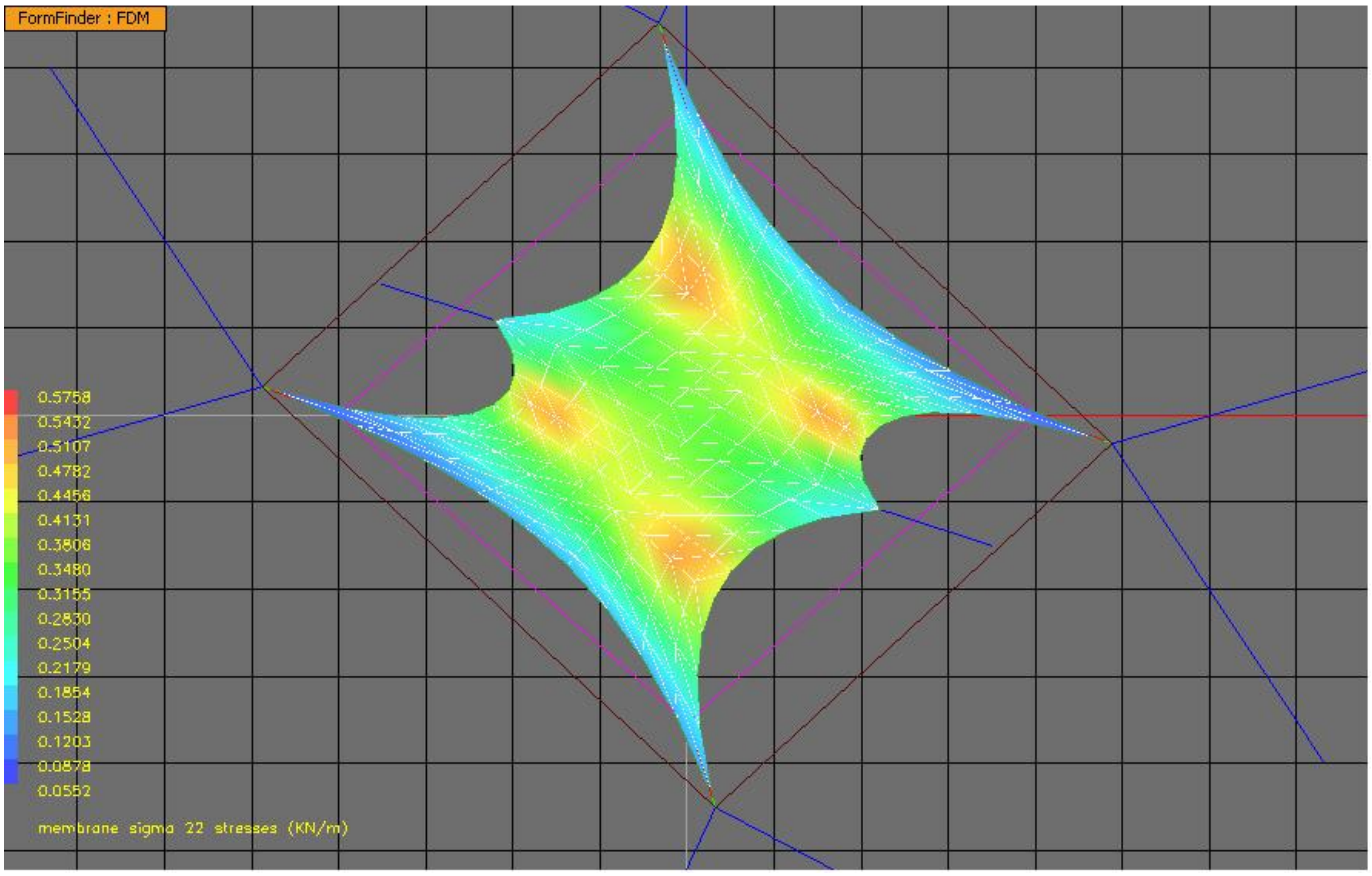
7 Planning cost Engineering			
about 30%	of building cost		
SUBTOTAL PLANNING COST ENGINEERING		**€**	**985.61**
TOTAL, INCLUDED PLANNING WITHOUT VAT		**€**	**7,071**

8	**Approval membrane**			
8.1	fees government structural verification			Client
8.2	fees government structural verification in single case			Client
8.3	testing membrane			
			€ total	**1000**

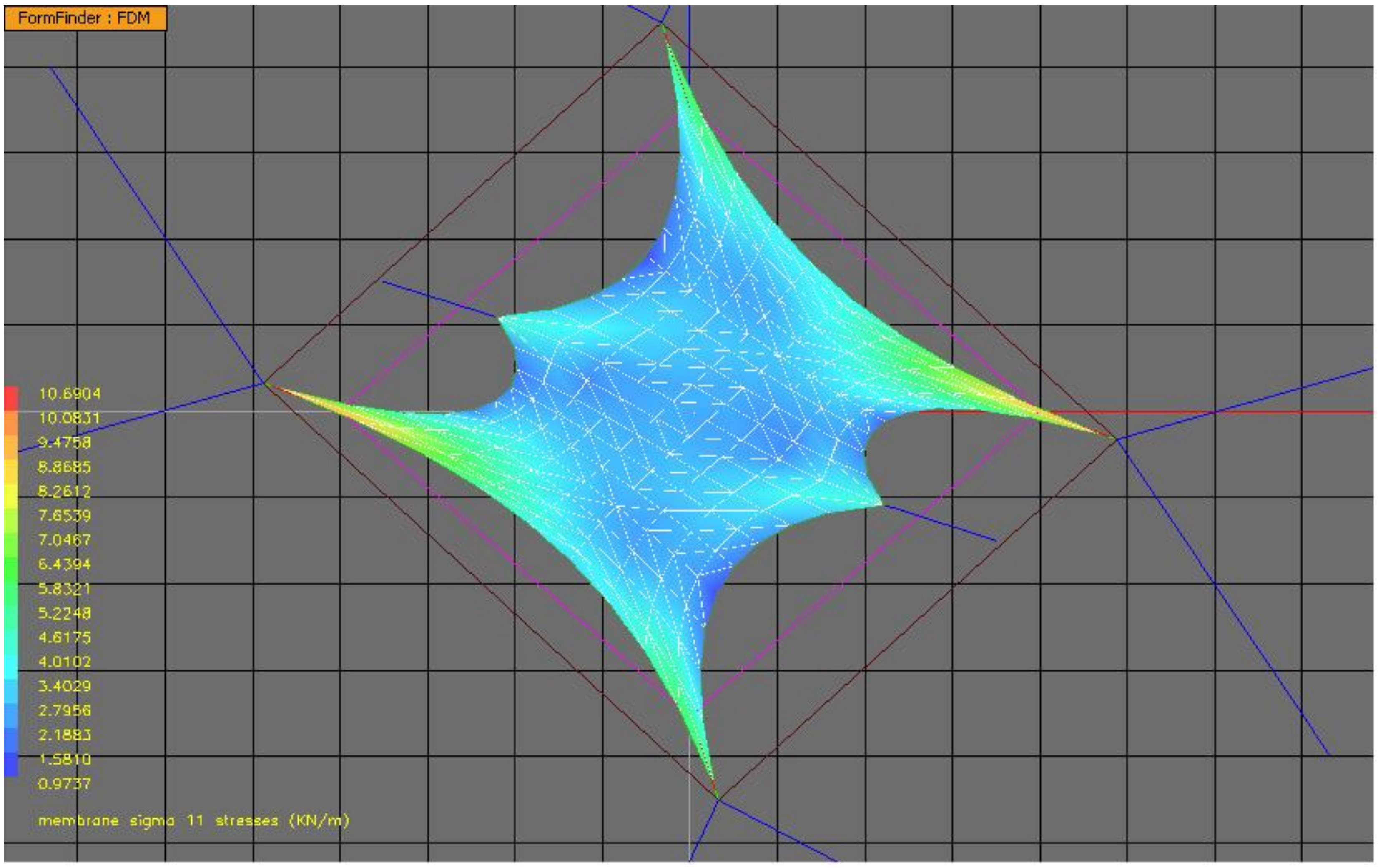
9.	**ON SITE TASKS**			
	SURVEYING	€	**500.00**	
10	**General Contractor addition**		0.10	**857.1**
Grand Total		**€**		**9428**

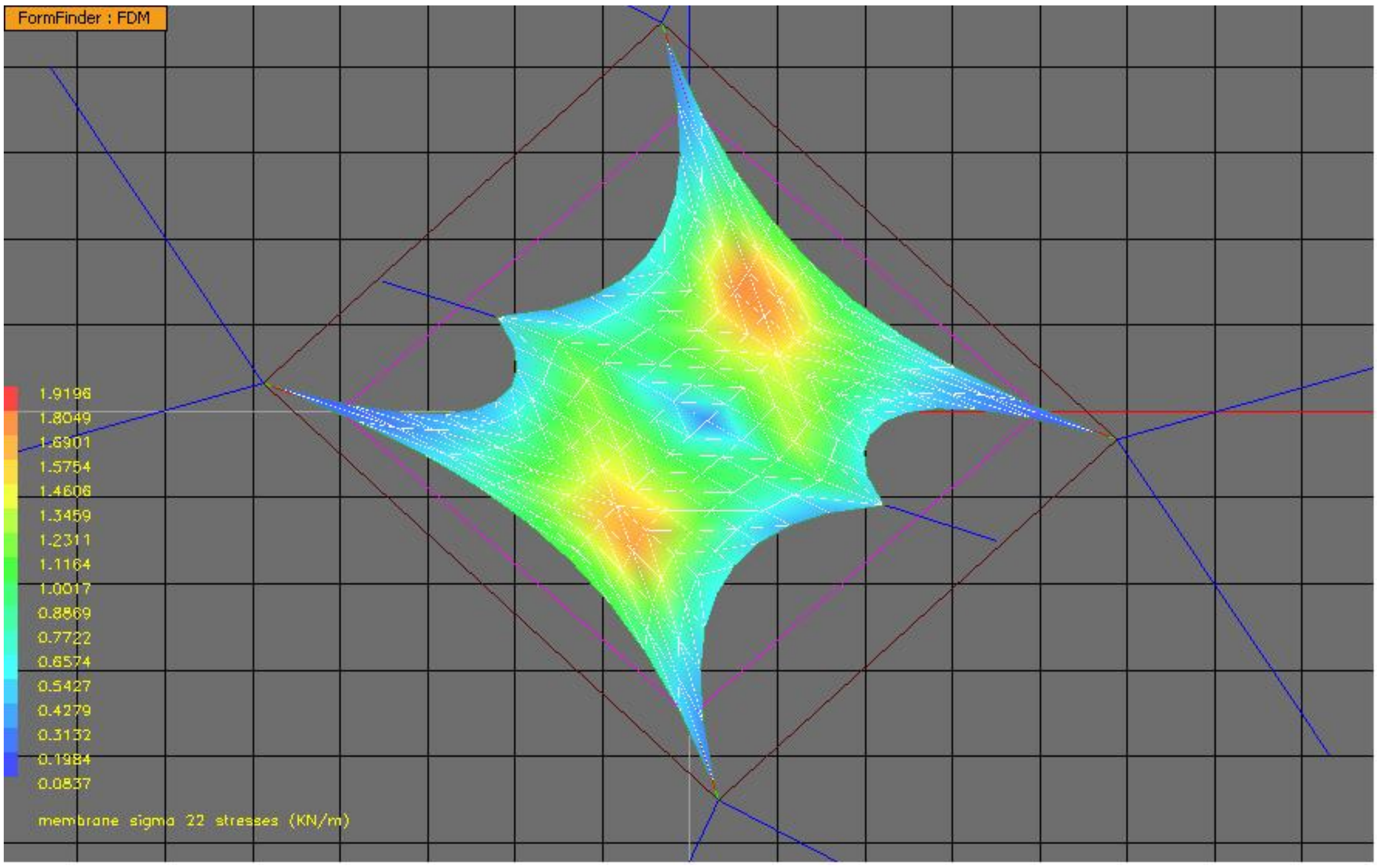
Appendix 03: Membrane Stresses in Different Load Combinations.
SLS01



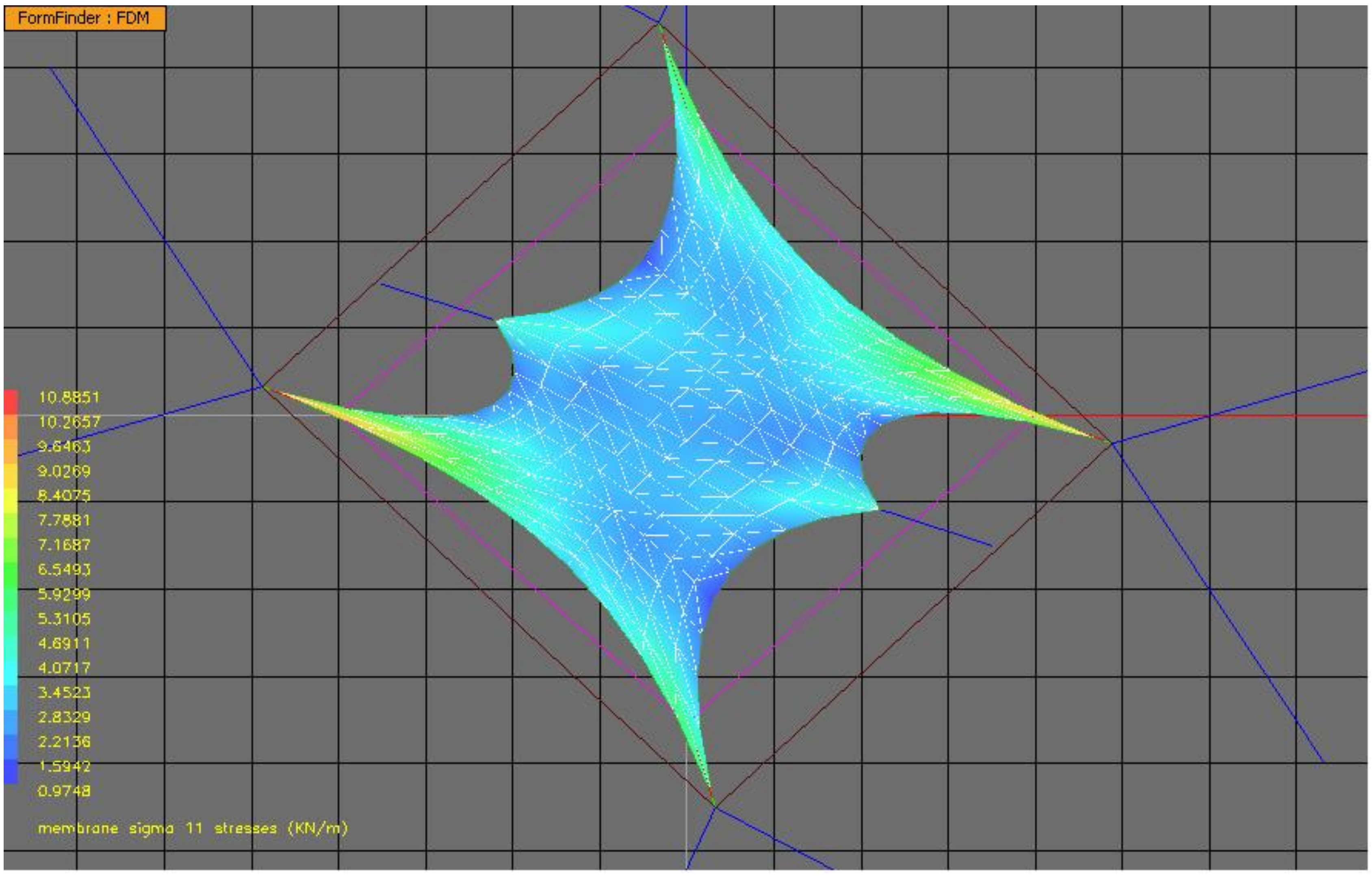


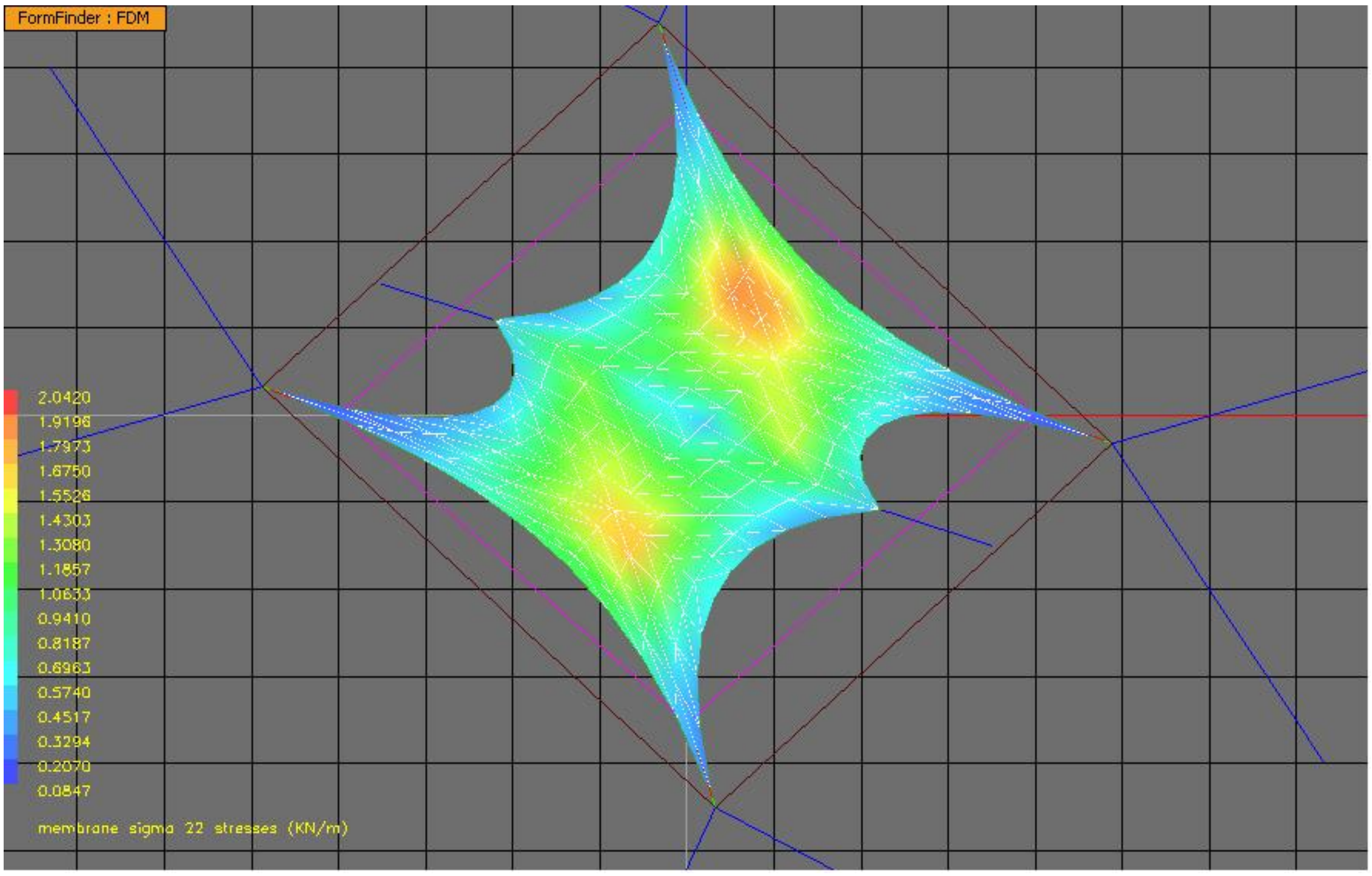
SLS02


FormFinder : FDM
10.6904
10.0831
9.4758
8.8685
8.2612
7.6539
7.0467
6.4394
5.8321
5.2248
4.6175
4.0102
3.4029
2.7956
2.1883
1.5810
0.9737
membrane sigma 11 stresses (KN/m)

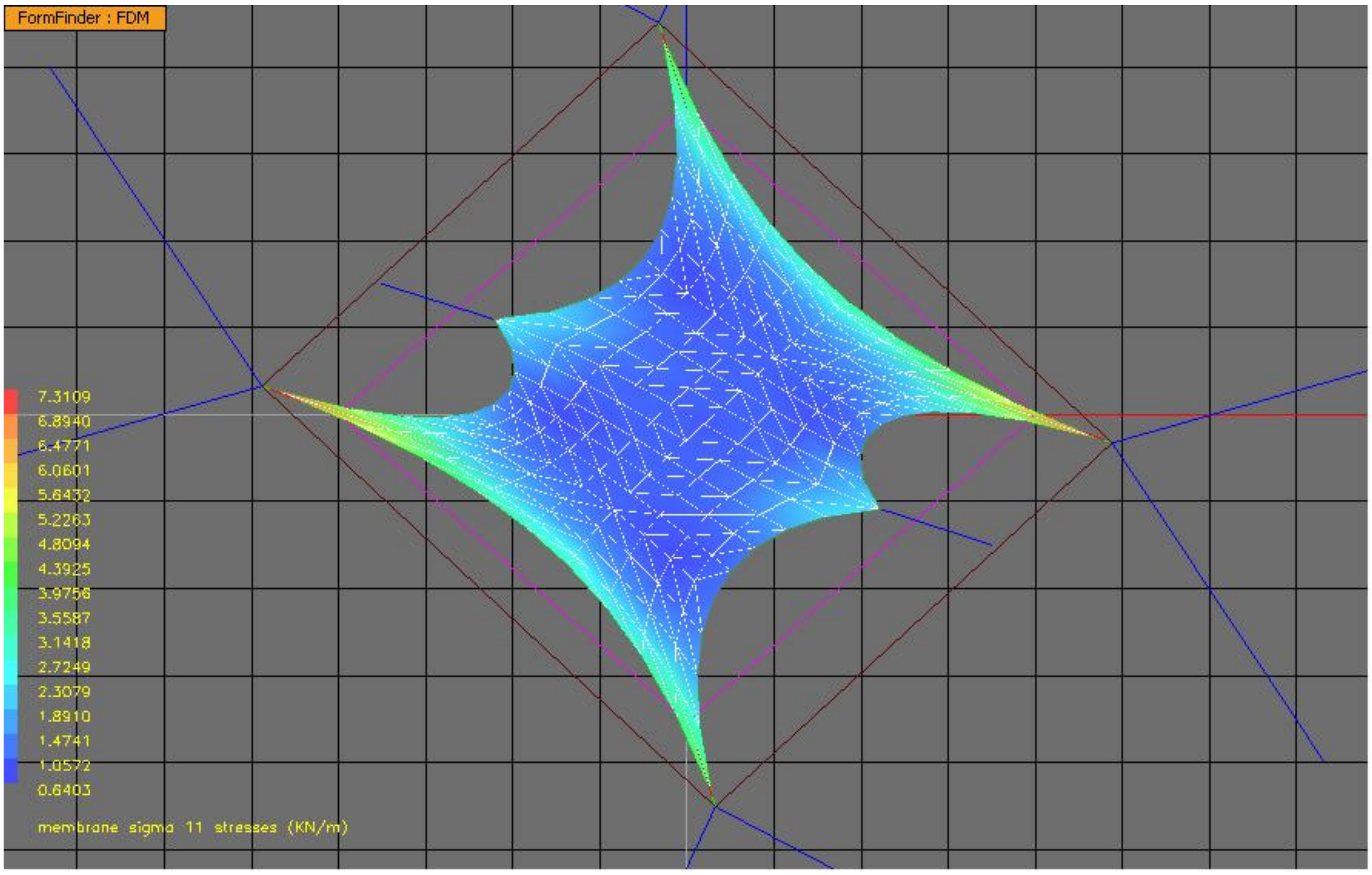

FormFinder : FDM
1.9196
1.8049
1.6901
1.5754
1.4606
1.3459
1.2311
1.1164
1.0017
0.8869
0.7722
0.6574
0.5427
0.4279
0.3132
0.1984
0.0837
membrane sigma 22 stresses (KN/m)

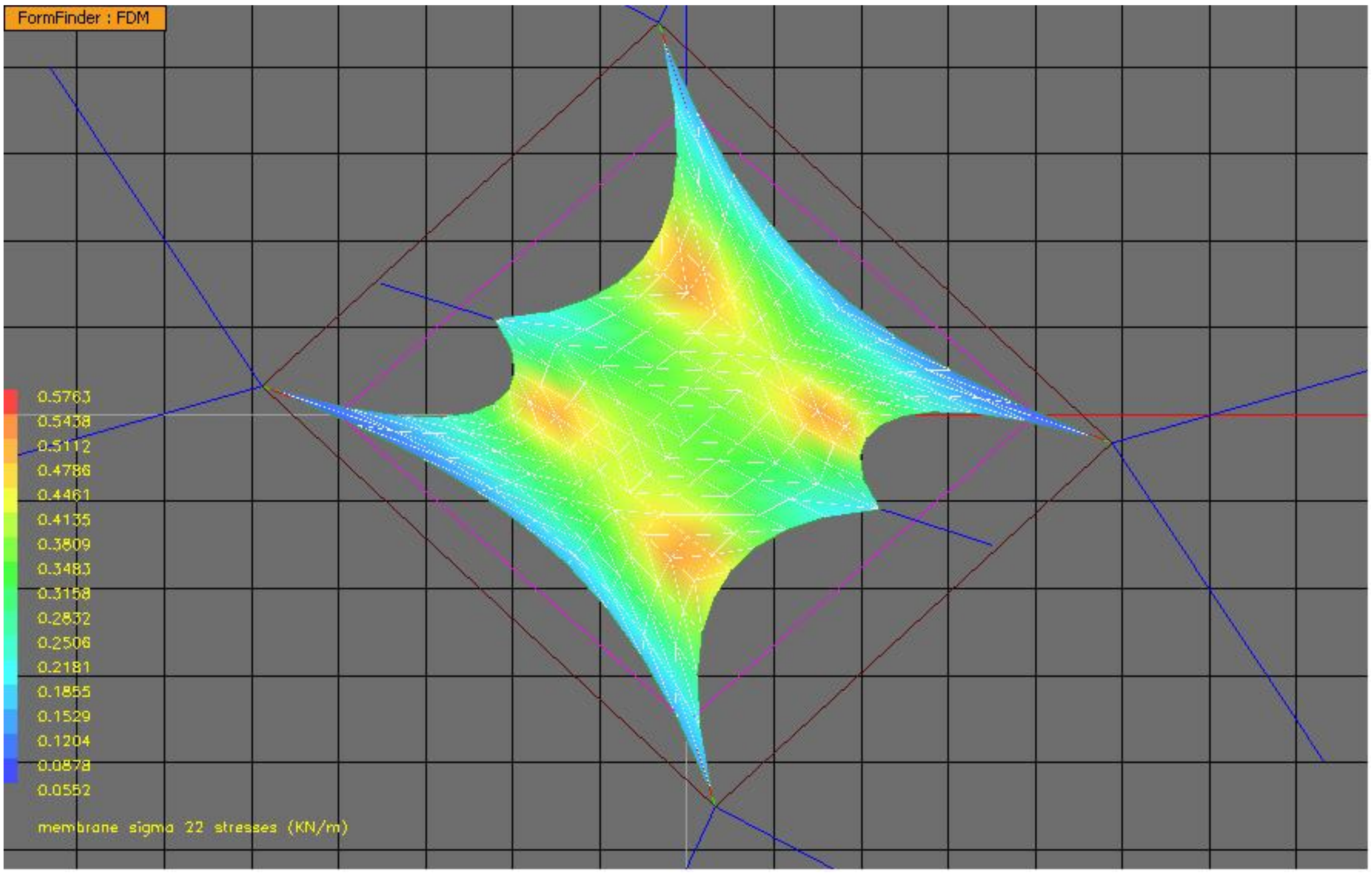
SLS03


FormFinder : FDM
10.8851
10.2657
9.6463
9.0269
8.4075
7.7881
7.1687
6.5493
5.9299
5.3105
4.6911
4.0717
3.4523
2.8329
2.2136
1.5942
0.9748
membrane sigma 11 stresses (KN/m)

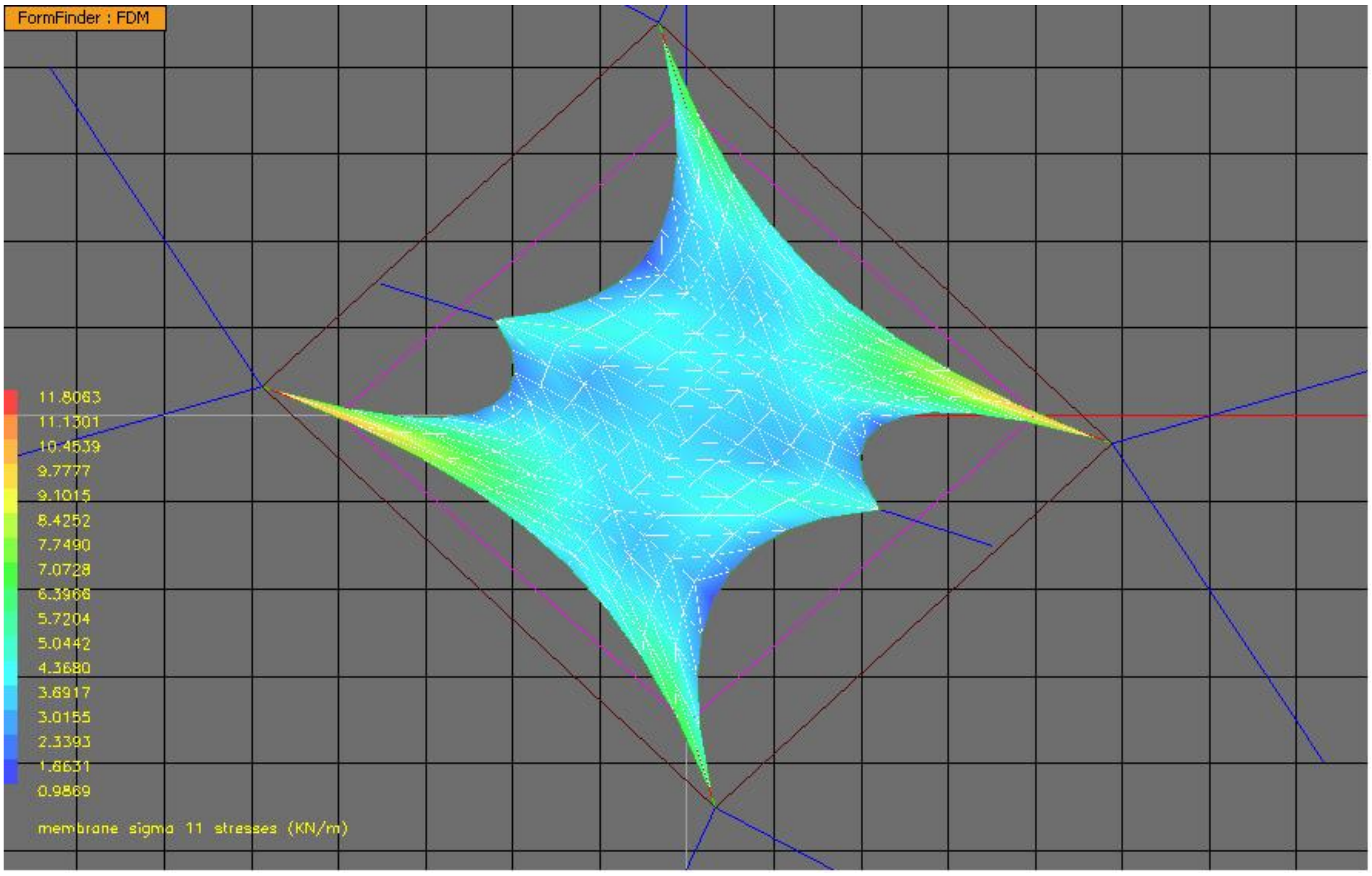

FormFinder : FDM
2.0420
1.9196
1.7973
1.6750
1.5526
1.4303
1.3080
1.1857
1.0633
0.9410
0.8187
0.6963
0.5740
0.4517
0.3294
0.2070
0.0847
membrane sigma 22 stresses (KN/m)

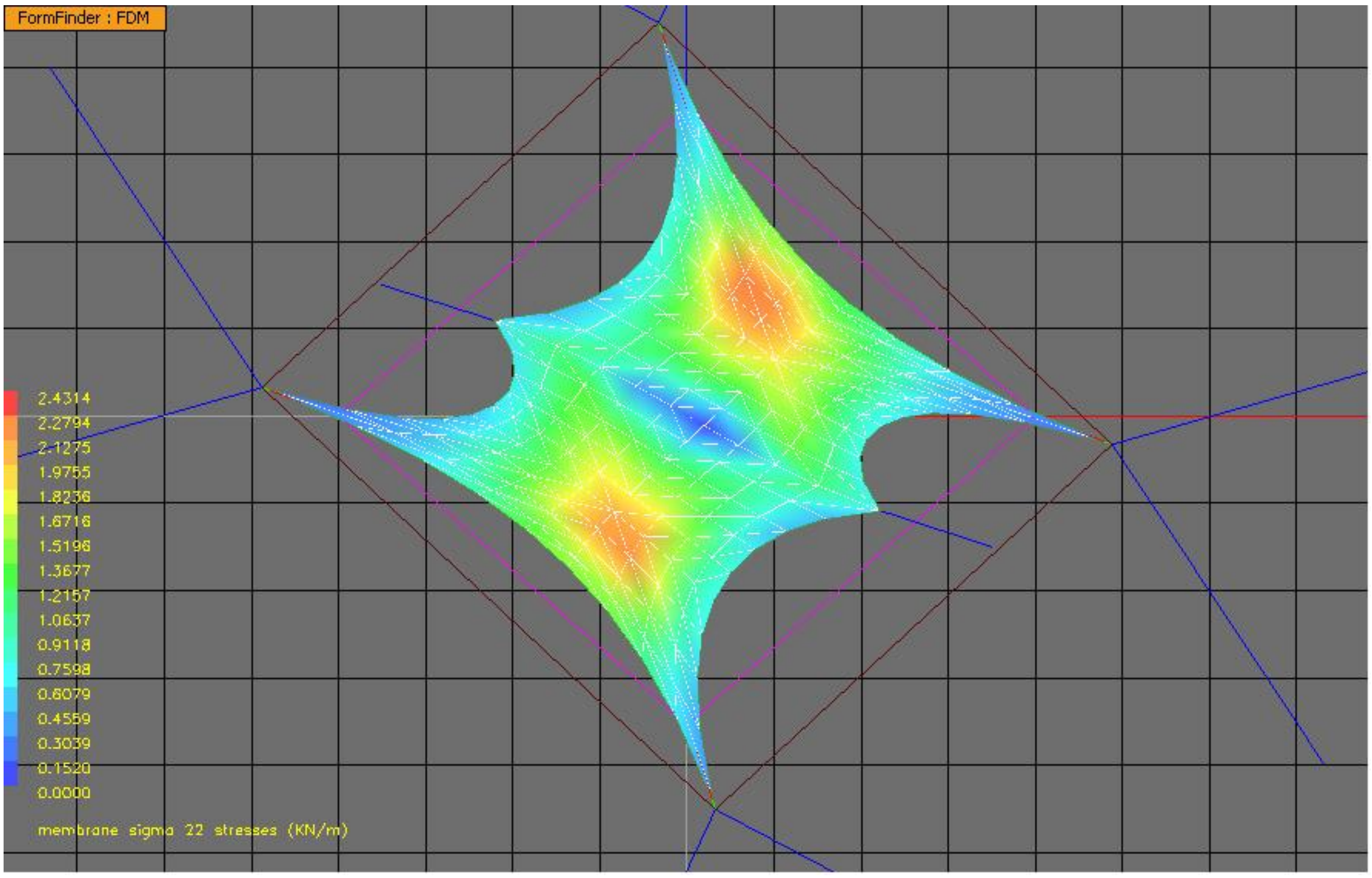
ULS01


FormFinder : FDM
7.3109
6.8940
6.4771
6.0601
5.6432
5.2263
4.8094
4.3925
3.9756
3.5587
3.1418
2.7249
2.3079
1.8910
1.4741
1.0572
0.6403
membrane sigma 11 stresses (KN/m)

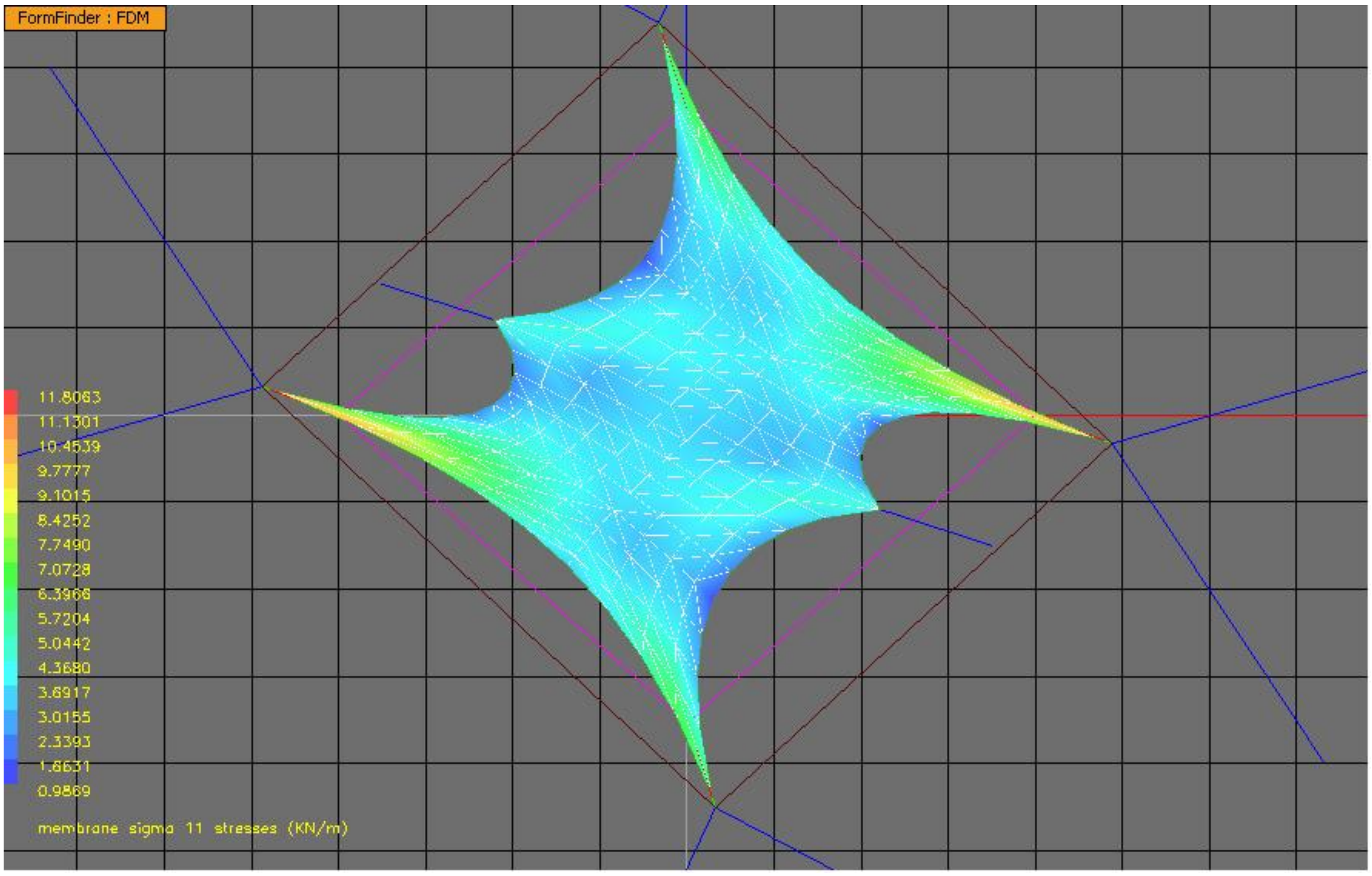

FormFinder : FDM
0.5763
0.5438
0.5112
0.4786
0.4461
0.4135
0.3809
0.3483
0.3158
0.2832
0.2506
0.2181
0.1855
0.1529
0.1204
0.0878
0.0552
membrane sigma 22 stresses (KN/m)

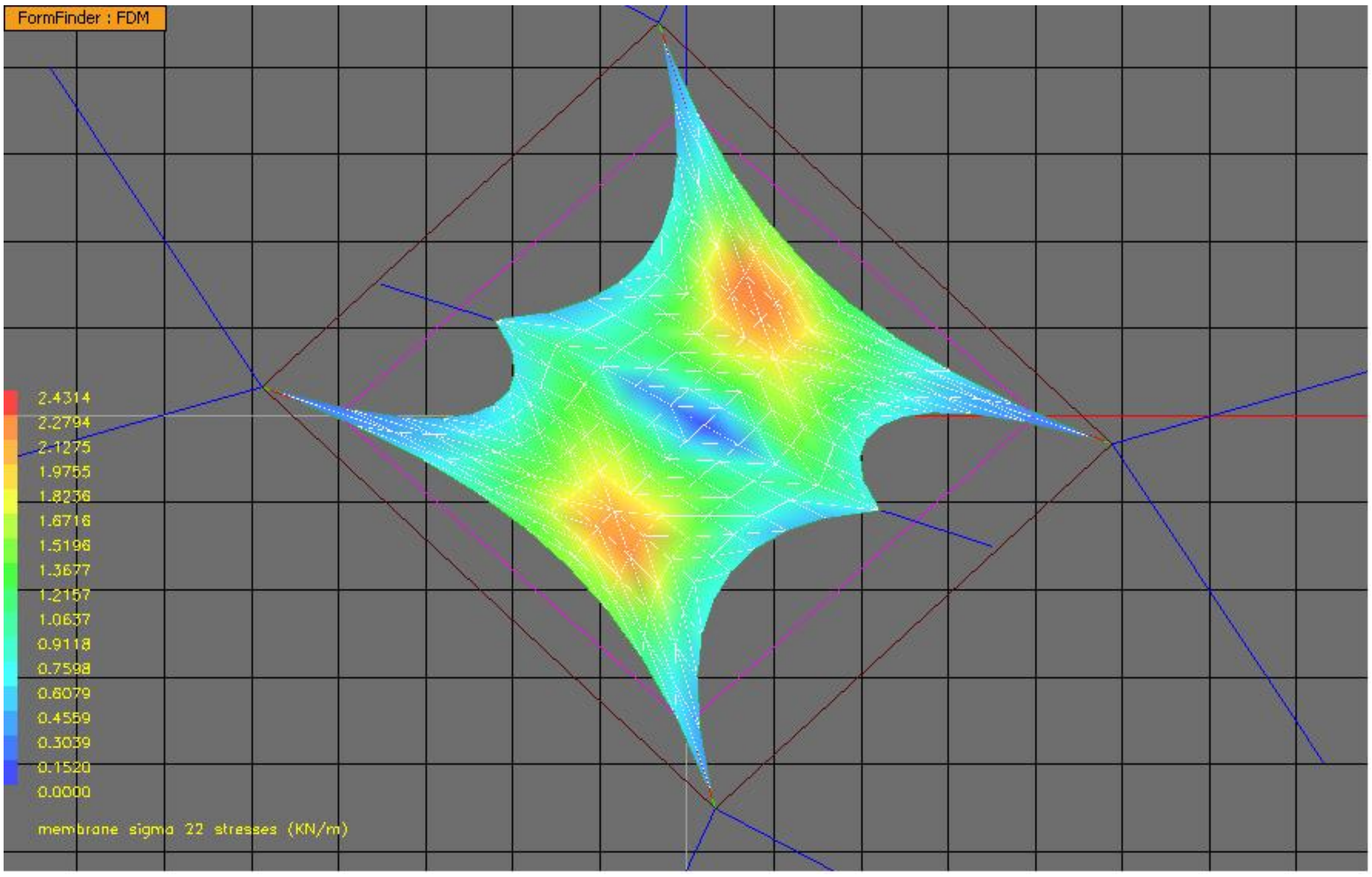
ULS02


FormFinder : FDM
11.8063
11.1301
10.4539
9.7777
9.1015
8.4252
7.7490
7.0728
6.3966
5.7204
5.0442
4.3680
3.6917
3.0155
2.3393
1.6631
0.9869
membrane sigma 11 stresses (KN/m)

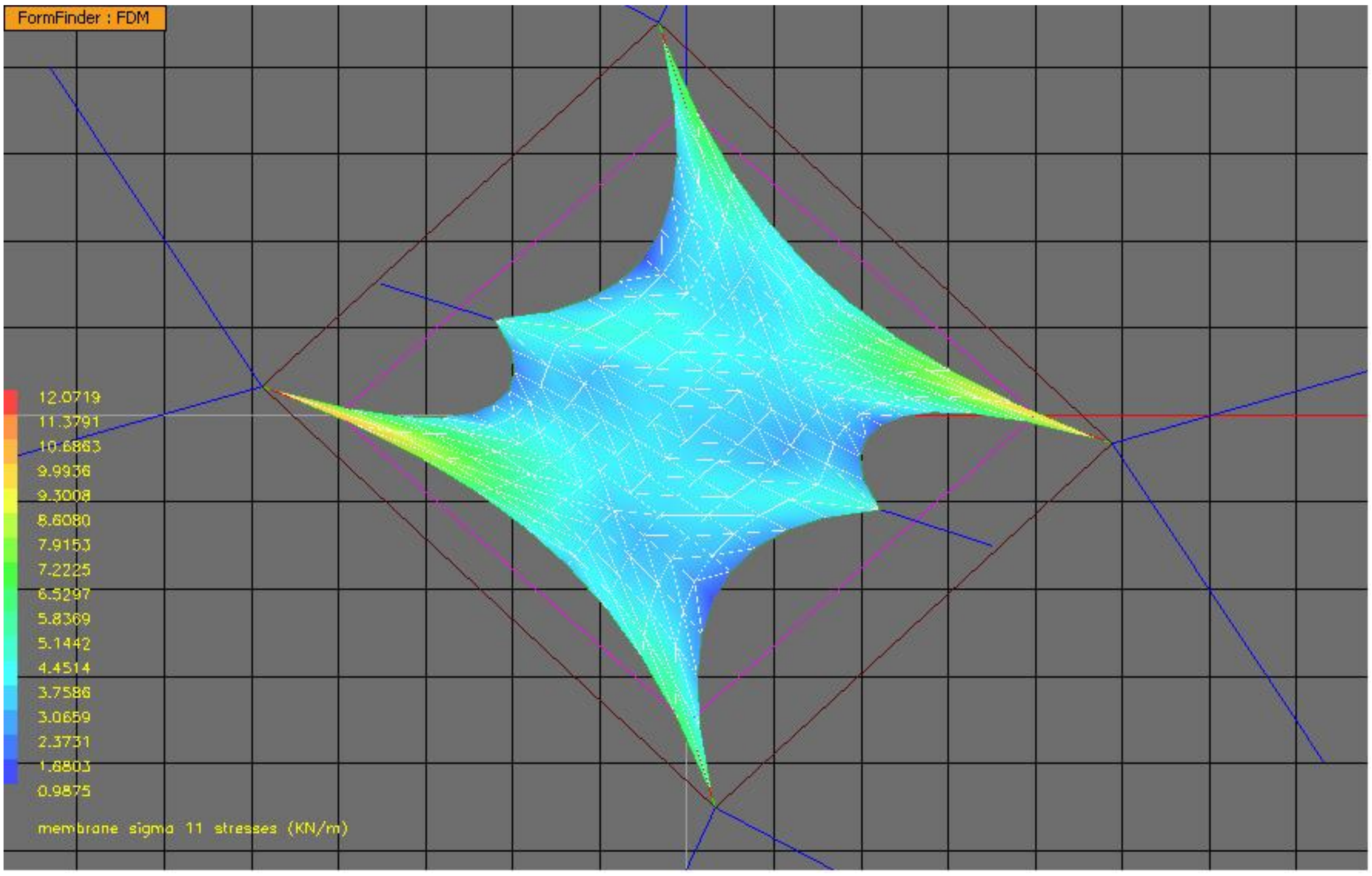

FormFinder : FDM
2.4314
2.2794
2.1275
1.9755
1.8236
1.6716
1.5196
1.3677
1.2157
1.0637
0.9118
0.7598
0.6079
0.4559
0.3039
0.1520
0.0000
membrane sigma 22 stresses (KN/m)

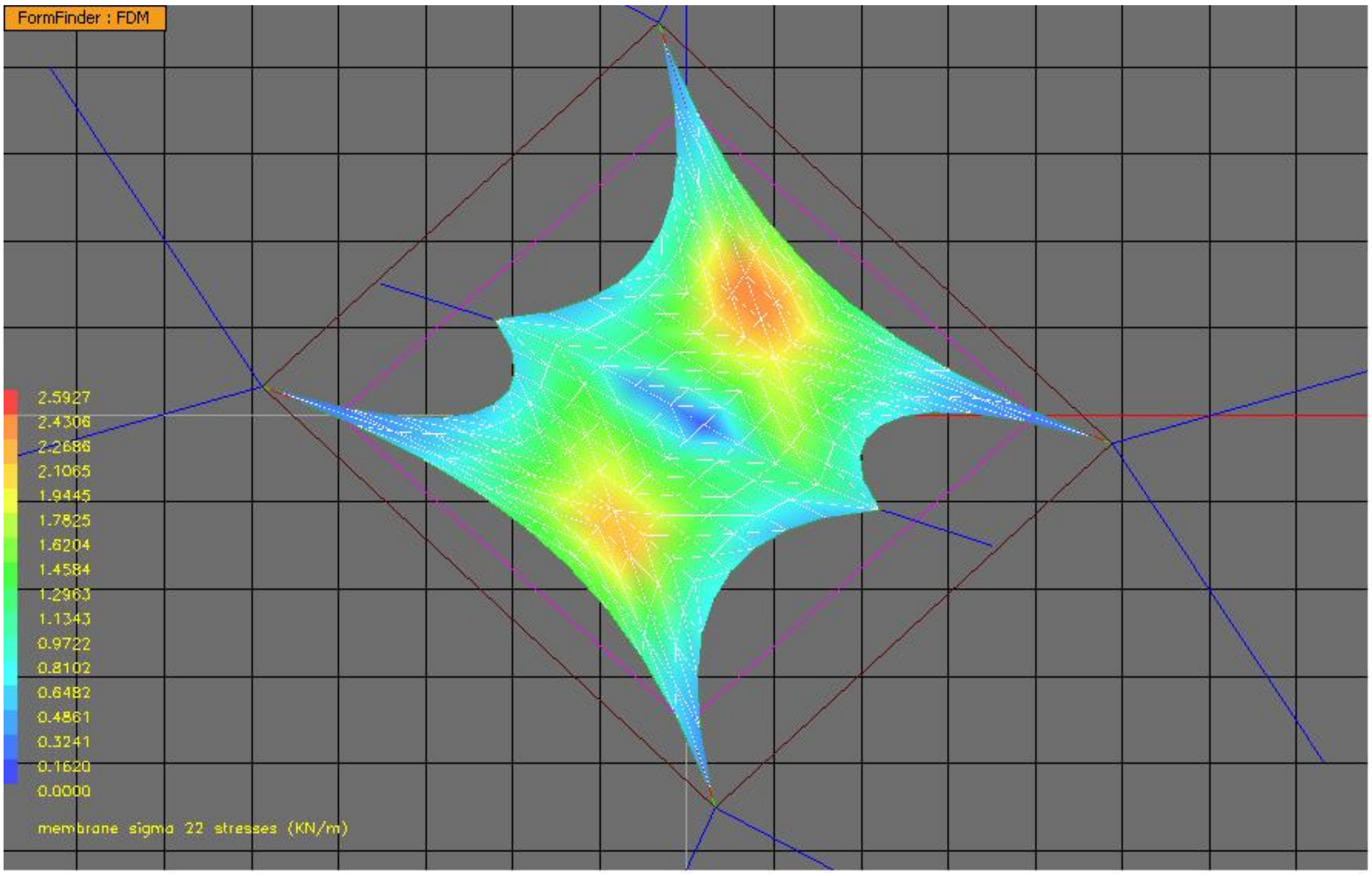
ULS02


FormFinder : FDM
11.8063
11.1301
10.4539
9.7777
9.1015
8.4252
7.7490
7.0728
6.3966
5.7204
5.0442
4.3680
3.6917
3.0155
2.3393
1.6631
0.9869
membrane sigma 11 stresses (KN/m)


FormFinder : FDM
2.4314
2.2794
2.1275
1.9755
1.8236
1.6716
1.5196
1.3677
1.2157
1.0637
0.9118
0.7598
0.6079
0.4559
0.3039
0.1520
0.0000
membrane sigma 22 stresses (KN/m)

ULS 03


FormFinder : FDM
12.0719
11.3791
10.6863
9.9936
9.3008
8.6080
7.9153
7.2225
6.5297
5.8369
5.1442
4.4514
3.7586
3.0659
2.3731
1.6803
0.9875
membrane sigma 11 stresses (KN/m)


FormFinder : FDM
2.5927
2.4306
2.2686
2.1065
1.9445
1.7825
1.6204
1.4584
1.2963
1.1343
0.9722
0.8102
0.6482
0.4861
0.3241
0.1620
0.0000
membrane sigma 22 stresses (KN/m)

Appendix 04: Forten Analysis Report

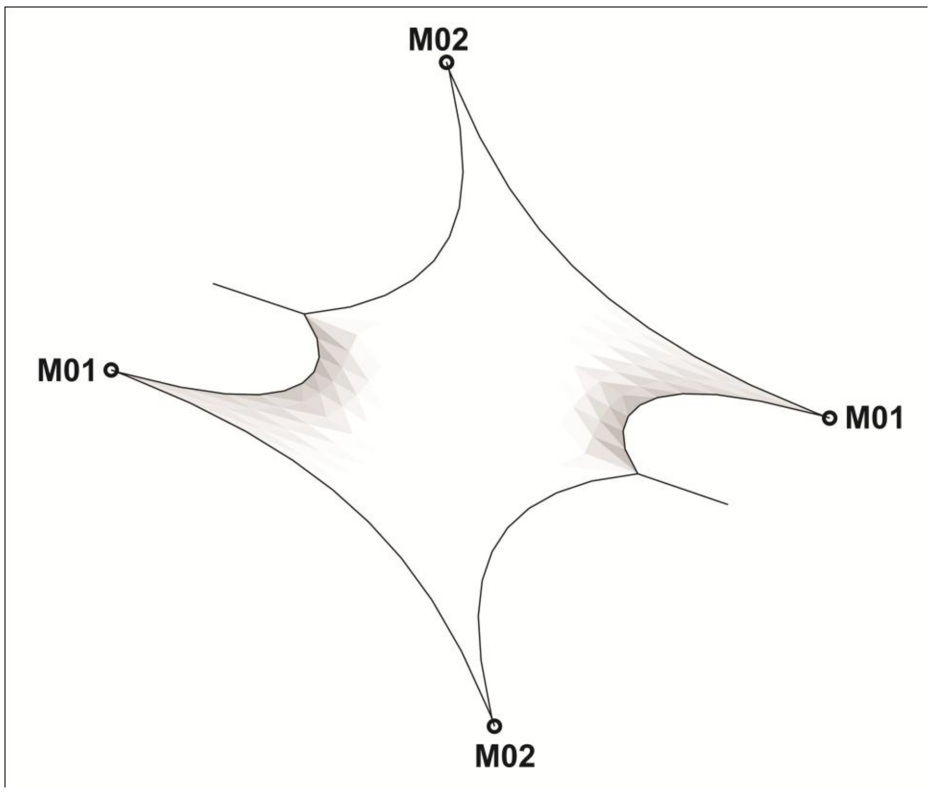


Figure 68: Mast Position

Mast M01 Report

work	SLS01:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
407	-5.362	0	0	0	0	0
407	-5.362	0	0	0	0	0
work	SLS02:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
407	-17.345	0	0	0	0	0
407	-17.345	0	0	0	0	0
work	SLS03:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
407	-17.657	0	0	0	0	0
407	-17.657	0	0	0	0	0
work	ULS01:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
407	-5.479	0	0	0	0	0
407	-5.479	0	0	0	0	0
work	ULS02:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
407	-22.74	0	0	0	0	0
407	-22.74	0	0	0	0	0
work	ULS03:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
407	-23.05	0	0	0	0	0
407	-23.05	0	0	0	0	0

Mast M02 Report

work	SLS01:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
405	-3.664	0	0	0	0	0
405	-3.664	0	0	0	0	0

work	SLS02:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
405	-12.068	0	0	0	0	0
405	-12.068	0	0	0	0	0

work	SLS03:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
405	-12.552	0	0	0	0	0
405	-12.552	0	0	0	0	0

work	ULS01:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
405	-3.72	0	0	0	0	0
405	-3.72	0	0	0	0	0

work	ULS02:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
405	-15.819	0	0	0	0	0
405	-15.819	0	0	0	0	0

work	ULS03:element results	Wed Jan 9 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
405	-16.455	0	0	0	0	0
405	-16.455	0	0	0	0	0

Stay Cable Type A Report

work	SLS01:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
415	1.994	0	0	0	0	0
416	1.708	0	0	0	0	0

work	SLS02:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
415	4.878	0	0	0	0	0
416	7.157	0	0	0	0	0

work	SLS03:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
415	4.629	0	0	0	0	0

416	7.335	0	0	0	0	0

work	ULS01:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
415	1.982	0	0	0	0	0
416	1.698	0	0	0	0	0

work	ULS02:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
415	6.06	0	0	0	0	0
416	9.556	0	0	0	0	0

work	ULS03:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
415	5.649	0	0	0	0	0
416	9.808	0	0	0	0	0

Stay Cable Type C Report

work	SLS01:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
410	2.025	0	0	0	0	0
409	1.794	0	0	0	0	0

work	SLS02:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
410	5.446	0	0	0	0	0
409	7.619	0	0	0	0	0

work	SLS03:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
410	6.048	0	0	0	0	0
409	7.718	0	0	0	0	0

work	ULS01:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
410	2.009	0	0	0	0	0
409	1.784	0	0	0	0	0

work	ULS02:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
410	6.891	0	0	0	0	0
409	10.138	0	0	0	0	0

work	ULS03:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m

410	7.749	0	0	0	0	0
409	10.235	0	0	0	0	0

Stay Cable Type E Report

work	SLS01:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
417	2.671	0	0	0	0	0

work	SLS02:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
417	4.319	0	0	0	0	0

work	SLS03:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
417	4.593	0	0	0	0	0

work	ULS01:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
417	2.663	0	0	0	0	0

work	ULS02:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
417	4.884	0	0	0	0	0

work	ULS03:element results	Tue Jan 8 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
417	5.233	0	0	0	0	0

Edge Cable Type E01 Repot

work	SLS01:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
369	0.539	0	0	0	0	0
370	0.403	0	0	0	0	0
371	0.344	0	0	0	0	0
372	0.312	0	0	0	0	0
373	0.296	0	0	0	0	0
374	0.295	0	0	0	0	0
375	0.313	0	0	0	0	0
376	0.355	0	0	0	0	0
377	0.456	0	0	0	0	0

work	SLS02:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
369	7.262	0	0	0	0	0
370	6.377	0	0	0	0	0

371	5.48	0	0	0	0	0
372	4.859	0	0	0	0	0
373	4.517	0	0	0	0	0
374	4.449	0	0	0	0	0
375	4.673	0	0	0	0	0
376	5.244	0	0	0	0	0
377	6.043	0	0	0	0	0

work	SLS03:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
369	7.374	0	0	0	0	0
370	6.429	0	0	0	0	0
371	5.491	0	0	0	0	0
372	4.825	0	0	0	0	0
373	4.483	0	0	0	0	0
374	4.429	0	0	0	0	0
375	4.657	0	0	0	0	0
376	5.202	0	0	0	0	0
377	5.918	0	0	0	0	0

work	ULS01:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
369	0.545	0	0	0	0	0
370	0.409	0	0	0	0	0
371	0.35	0	0	0	0	0
372	0.317	0	0	0	0	0
373	0.301	0	0	0	0	0
374	0.3	0	0	0	0	0
375	0.317	0	0	0	0	0
376	0.36	0	0	0	0	0
377	0.462	0	0	0	0	0

work	ULS02:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
369	10.035	0	0	0	0	0
370	8.929	0	0	0	0	0
371	7.726	0	0	0	0	0
372	6.855	0	0	0	0	0
373	6.361	0	0	0	0	0
374	6.255	0	0	0	0	0
375	6.559	0	0	0	0	0
376	7.328	0	0	0	0	0
377	8.348	0	0	0	0	0

work	ULS03:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
369	10.159	0	0	0	0	0
370	8.971	0	0	0	0	0
371	7.718	0	0	0	0	0
372	6.784	0	0	0	0	0
373	6.295	0	0	0	0	0
374	6.212	0	0	0	0	0
375	6.525	0	0	0	0	0
376	7.258	0	0	0	0	0
377	8.162	0	0	0	0	0

Stay Cable Type E02 Report

work	SLS01:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
387	1.09	0	0	0	0	0
388	0.811	0	0	0	0	0
389	0.65	0	0	0	0	0
390	0.547	0	0	0	0	0
391	0.482	0	0	0	0	0
392	0.451	0	0	0	0	0
393	0.459	0	0	0	0	0
394	0.514	0	0	0	0	0
395	0.629	0	0	0	0	0

work	SLS02:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
387	2.155	0	0	0	0	0
388	1.728	0	0	0	0	0
389	1.382	0	0	0	0	0
390	1.127	0	0	0	0	0
391	0.965	0	0	0	0	0
392	0.881	0	0	0	0	0
393	0.867	0	0	0	0	0
394	0.925	0	0	0	0	0
395	1.165	0	0	0	0	0

work	SLS03:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
387	2.273	0	0	0	0	0
388	1.842	0	0	0	0	0
389	1.483	0	0	0	0	0
390	1.216	0	0	0	0	0
391	1.047	0	0	0	0	0
392	0.961	0	0	0	0	0
393	0.953	0	0	0	0	0
394	1.032	0	0	0	0	0
395	1.311	0	0	0	0	0

work	ULS01:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
387	1.096	0	0	0	0	0
388	0.815	0	0	0	0	0
389	0.652	0	0	0	0	0
390	0.548	0	0	0	0	0
391	0.483	0	0	0	0	0
392	0.452	0	0	0	0	0
393	0.459	0	0	0	0	0
394	0.513	0	0	0	0	0
395	0.627	0	0	0	0	0

work	ULS02:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m

387	2.821	0	0	0	0	0
388	2.305	0	0	0	0	0
389	1.852	0	0	0	0	0
390	1.5	0	0	0	0	0
391	1.268	0	0	0	0	0
392	1.144	0	0	0	0	0
393	1.108	0	0	0	0	0
394	1.171	0	0	0	0	0
395	1.479	0	0	0	0	0

work	ULS03:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
387	2.901	0	0	0	0	0
388	2.387	0	0	0	0	0
389	1.929	0	0	0	0	0
390	1.571	0	0	0	0	0
391	1.339	0	0	0	0	0
392	1.217	0	0	0	0	0
393	1.194	0	0	0	0	0
394	1.284	0	0	0	0	0
395	1.621	0	0	0	0	0

Stay Cable Type E03 Report

work	SLS01:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
351	0.921	0	0	0	0	0
352	0.679	0	0	0	0	0
353	0.547	0	0	0	0	0
354	0.476	0	0	0	0	0
355	0.452	0	0	0	0	0
356	0.466	0	0	0	0	0
357	0.519	0	0	0	0	0
358	0.612	0	0	0	0	0
359	0.763	0	0	0	0	0

work	SLS02:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
351	1.514	0	0	0	0	0
352	1.197	0	0	0	0	0
353	0.969	0	0	0	0	0
354	0.833	0	0	0	0	0
355	0.787	0	0	0	0	0
356	0.807	0	0	0	0	0
357	0.877	0	0	0	0	0
358	0.999	0	0	0	0	0
359	1.302	0	0	0	0	0

work	SLS03:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
351	1.708	0	0	0	0	0
352	1.374	0	0	0	0	0
353	1.129	0	0	0	0	0
354	0.979	0	0	0	0	0

355	0.919	0	0	0	0	0
356	0.932	0	0	0	0	0
357	1.001	0	0	0	0	0
358	1.131	0	0	0	0	0
359	1.461	0	0	0	0	0

work	ULS01:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
351	0.922	0	0	0	0	0
352	0.679	0	0	0	0	0
353	0.547	0	0	0	0	0
354	0.476	0	0	0	0	0
355	0.451	0	0	0	0	0
356	0.465	0	0	0	0	0
357	0.517	0	0	0	0	0
358	0.61	0	0	0	0	0
359	0.761	0	0	0	0	0

work	ULS02:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
351	1.88	0	0	0	0	0
352	1.509	0	0	0	0	0
353	1.226	0	0	0	0	0
354	1.051	0	0	0	0	0
355	0.986	0	0	0	0	0
356	1.005	0	0	0	0	0
357	1.086	0	0	0	0	0
358	1.231	0	0	0	0	0
359	1.593	0	0	0	0	0

work	ULS03:element results	Mon Jan 7 2013				
N°	N KN	V2 KN	V3 KN	T KN m	M2 KN m	M3 KN m
351	2.127	0	0	0	0	0
352	1.738	0	0	0	0	0
353	1.434	0	0	0	0	0
354	1.241	0	0	0	0	0
355	1.16	0	0	0	0	0
356	1.168	0	0	0	0	0
357	1.244	0	0	0	0	0
358	1.395	0	0	0	0	0
359	1.78	0	0	0	0	0

Appendix 05: Foundation Detail Drawing

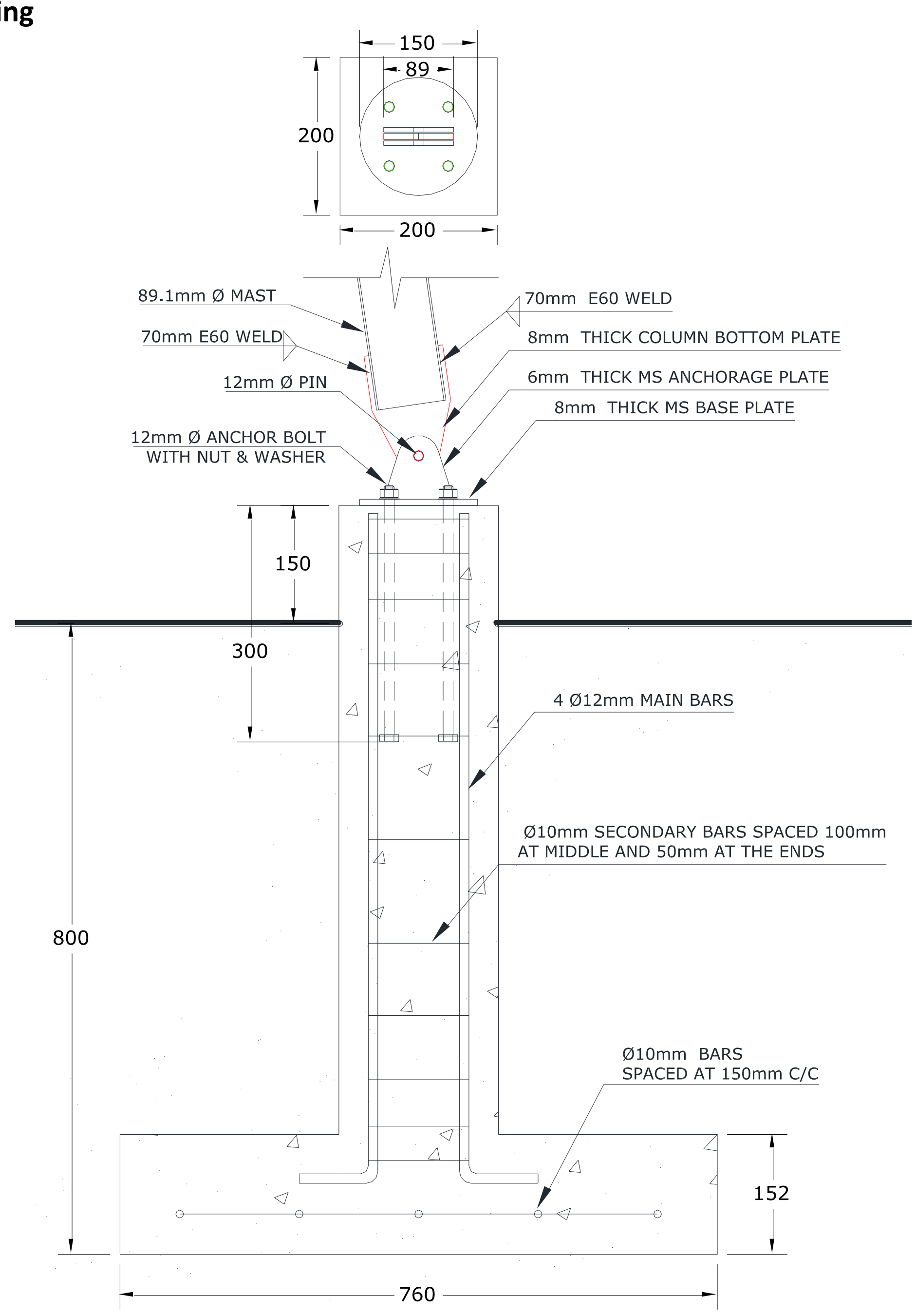


Figure 69: Footing F01

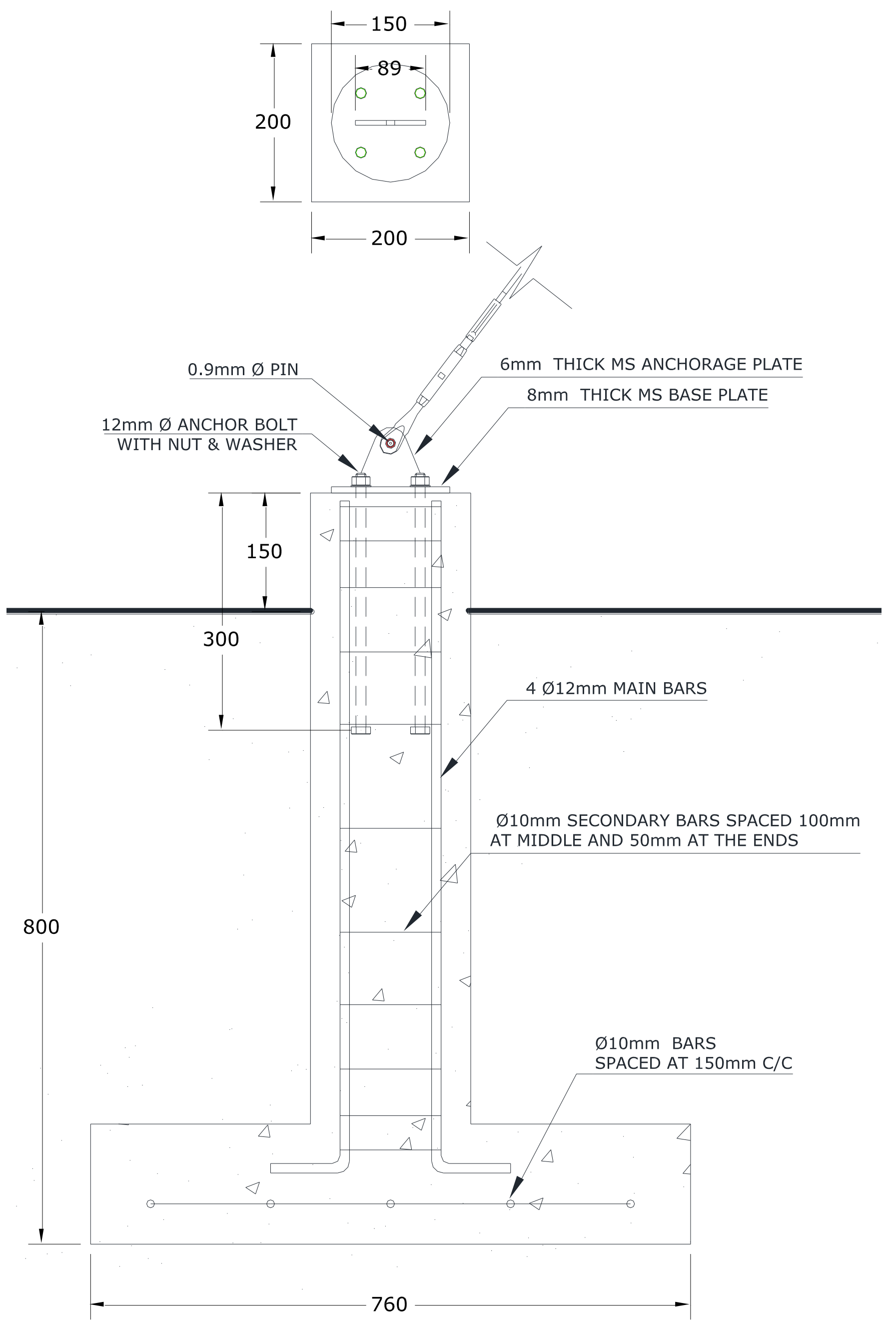
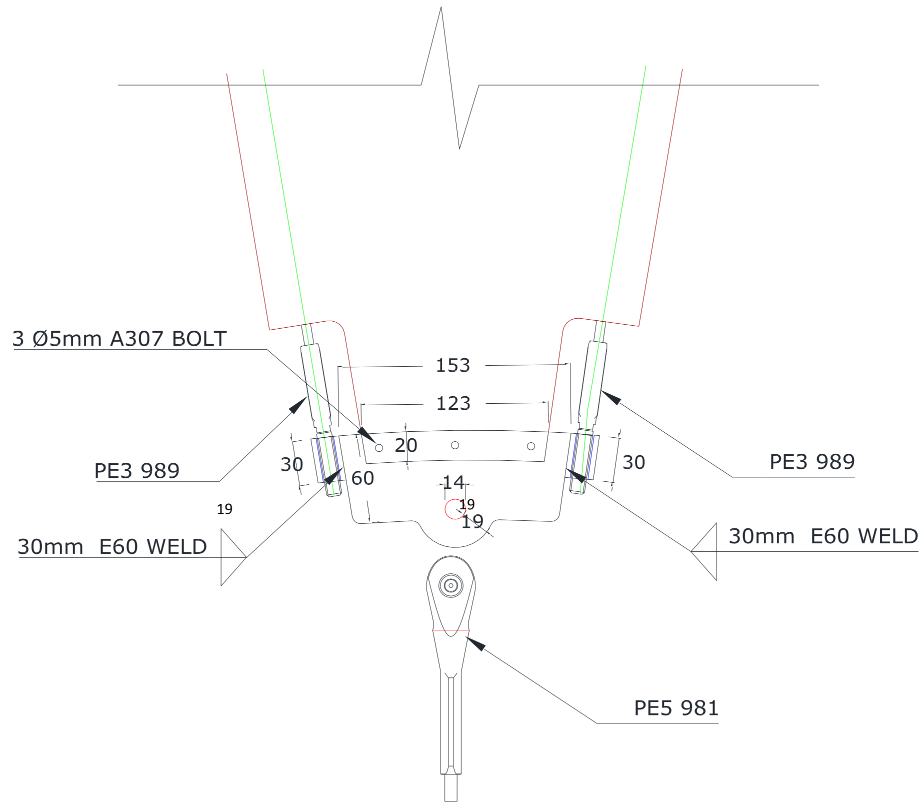


Figure 70: Footing F02

Appendix 05: Structural Calculation



Design of the Corner Plate CP01

Plate size

Here

F_y= 24.5 KN/cm^2 For A36 steel

ϕ_b= 0.75

l= 15.28 cm

w= 0.121 KN/cm for fabric

P= 15 KN for edge cables

M_1= $wl^2/8$

= 3.53 KN-cm

M_2= Pl/4

= 57.30 KN-cm

M= M_1+M_2

= 60.83 KN-cm

Z= M/F_y

2.48 cm^3

Z= $bh^2/6$

Assume thichness of the plate 6mm

b= 0.6 cm

Then h= 4.98 cm Use 6cm Plate

Clamping plate size

F_y= 24.5 KN/cm^2 For A36 steel

l= 5 cm

w= 0.121 KN/cm

M_n= $wl^2/8$

0.38 KN-cm

Z= M_n/F_y

0.01543 cm^3

Z= $bh^2/6$

Assume thichness of the plate 3mm

b= 0.3 cm

Then h= 0.56 cm

use 2 cm plate

Design of bolts in clamping plate

ϕ= 0.75

F_v= 16.5 KN/cm^2 For A307 bolts

w= 0.121 KN/cm

l= 12.3 cm

R_b= $\phi * F_v * A_v$

Assume 3 bolts

Load on bolts= wxl 1.5 KN

Load on each bolts= 0.50 KN

Then

A_v= 0.04 cm^2

Required dia d= 0.23 cm

use 5mm bolts

Design of weld on arms Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= $0.6*F_{E60}$

Design strength per cm for .3cm of weld= $0.75*0.6*F_{E60}*0.707*0.3$

= 4.0 KN/cm

Load on weld= 13 KN

No. of weld= 2

Load per weld= 6.5 KN

Required weld length= 1.62 cm

use 3cm weld

Design of the tube for edge cable

Load= 13 KN

F_y= 24.5 KN/cm^2

Area required to resist A= 0.53 cm^2

Inner dia of the tube for cable end PE03 is 1.2 cm

Then, outer area- inner area= 0.48 cm^2

Thickness t= 0.25 cm

use 0.35cm thick tube

Design of the pin in double shear

ϕ= 0.75

F_u= 40 KN/cm^2 ultimate strength

Area in shear A_{sf}

Design load P_d= $\phi*0.6*F_u*A_{sf}$

Design load 15 KN

Then A_{sf}= $P_d/(\phi*0.6*F_u)$

= 0.83 cm^2

Area of the pin= 0.42 cm^2

Dia of the pin d= 0.73 cm

use 1.2cm pin PE 5

Design of the pin in bearing

ϕ= 0.75

F_y= 24.5 KN/cm^2 ultimate strength

Area in shear d_b*t

Design load P_d= $\phi*1.8*F_y*d_b*t$

Design load 15 KN

d_b= 1.2 cm

Thickness t= 0.38 cm

use 0.6cm thick plate

Design of the plate in tension

ϕ= 0.75

F_u= 40 KN/cm^2

Thickeness t= 0.6 cm

Dia of pin d= 1.2 cm

Tension load = 15 KN

Tension load P_t= $\phi*F_v*A_e$

Area in tension A_e= $P_t/(\phi*F_v)$

= 0.5 cm^2

Gross Area A_g= $A_e+(d+.15)*t$

= 1.31 cm^2

Length in tension L_t= A_g/t

= 2.18 cm

Edge distance of the pin= 1.5*d

= 1.8 cm use 1.9 cm

Edge distance on both side= 3.6 cm

3.6 > 2.18 OK

Design of the Corner Plate CP02

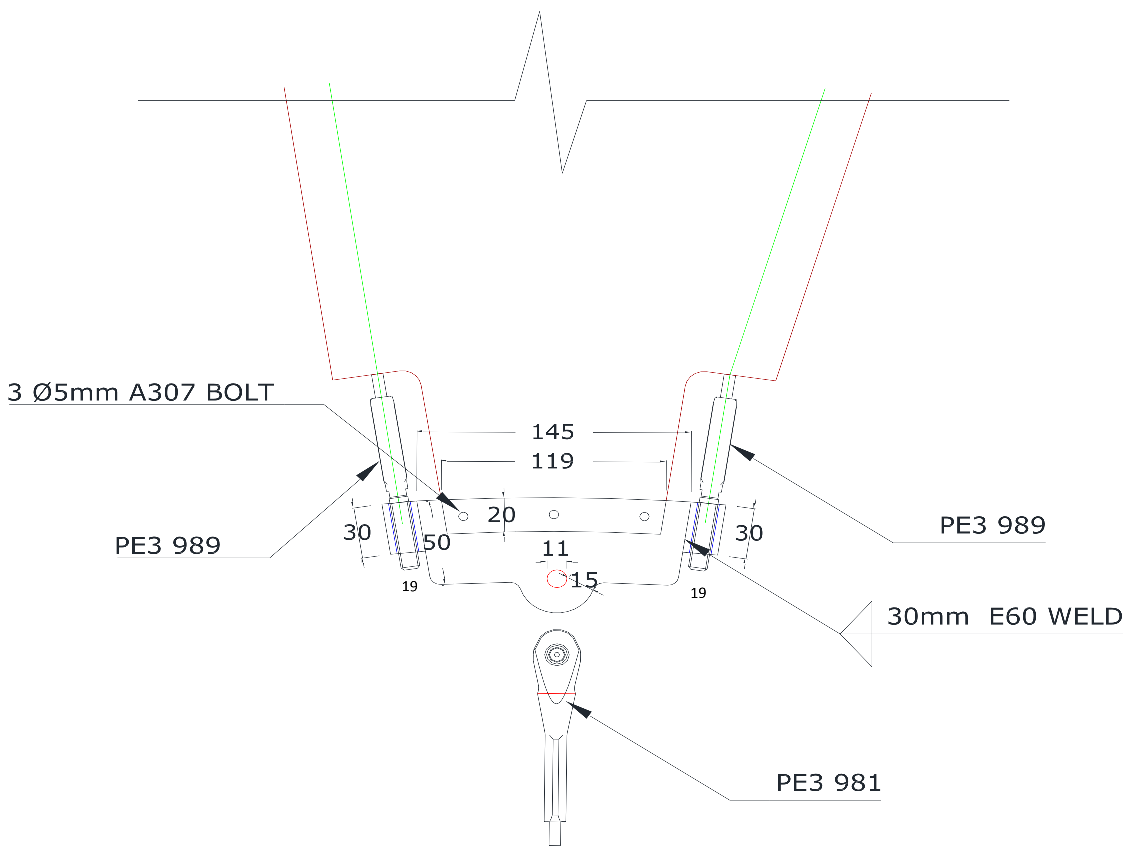


Plate size

Here

F_y= 24.5 KN/cm^2 For A36 steel

ϕ_b= 0.75

l= 14.5 cm

w= 0.076 KN/cm for fabric

P= 12 KN for edge cables

M_1= $wl^2/8$

= 2.00 KN-cm

M_2= Pl/4

= 43.50 KN-cm

M= M_1+M_2

= 45.50 KN-cm

Z= M/F_y

1.86 cm^3

Z= $bh^2/6$

Assume thichness of the plate 6mm

b= 0.6 cm

Then h= 4.31 cm Use 5cm Plate

Clamping plate size

F_y= 24.5 KN/cm^2 For A36 steel

l= 4.8 cm

w= 0.076 KN/cm

M_n= $wl^2/8$

0.22 KN-cm

Z= M_n/F_y

0.008934 cm^3

Z= $bh^2/6$

Assume thichness of the plate 3mm

b= 0.3 cm

Then h= 0.42 cm

use 2 cm plate

Design of bolts in clamping plate

ϕ= 0.75

F_v= 16.5 KN/cm^2 For A307 bolts

w= 0.076 KN/cm

l= 12 cm

R_b= ϕ* F_v*A_v
Assume 3 bolts
Load on bolts= wxl 0.9 KN
Load on each bolts= 0.30 KN
Then
A_v= 0.02 cm^2
Required dia d= 0.18 cm
use 5mm bolts

Design of weld on arms Fillet type weld
ϕ= 0.75
F_{E60}= 42 KN/cm^2
F_w= 0.6*F_{E60}
Design strength per cm for .3cm of weld= 0.75*0.6*F_{E60}*0.707*0.3
= 4.0 KN/cm
Load on weld= 12.3 KN
No. of weld= 2
Load per weld= 6.15 KN
Required weld length= 1.53 cm
use 3cm weld

Design of the tube for edge cable
Load= 12.3 KN
F_y= 24.5 KN/cm^2
Area required to resist A= 0.50 cm^2
Inner dia of the tube for cable end PE03 is 1.2 cm
Then, outer area- inner area= 0.48 cm^2
Thickness t= 0.24 cm
use 0.35cm thick tube

Design of the pin in double shear
ϕ= 0.75
F_u= 40 KN/cm^2 ultimate strength
Area in shear A_{sf}
Design load P_d= ϕ*0.6* F_u* A_{sf}
Design load 12 KN
Then A_{sf}= P_d/(ϕ*0.6* F_u)
= 0.67 cm^2
Area of the pin= 0.33 cm^2
Dia of the pin d= 0.65 cm
use .9cm pin PE 3

Design of the pin in bearing
ϕ= 0.75
F_y= 24.5 KN/cm^2 ultimate strength
Area in shear d_b*t
Design load P_d= ϕ*1.8* F_y* d_b*t
Design load 12 KN
d_b= 1.05 cm
Thickness t= 0.35 cm
use 0.6cm thick plate

Design of the plate in tension
ϕ= 0.75
F_u= 40 KN/cm^2
Thickeness t= 0.6 cm
Dia of pin d= 0.9 cm
Tension load = 12 KN
Tension load P_t= ϕ* F_v*A_e
Area in tension A_e= P_t/(ϕ* F_v)
= 0.4 cm^2
Gross Area A_g= A_e+(d+.15)*t
= 1.03 cm^2
Length in tension L_t= A_g/t
= 1.72 cm
Edge distance of the pin= 1.5*d
= 1.35 cm use 1.5cm
Edge distance on both side= 2.7 cm
2.7 > 1.72 OK

Design of the Corner Plate CP03

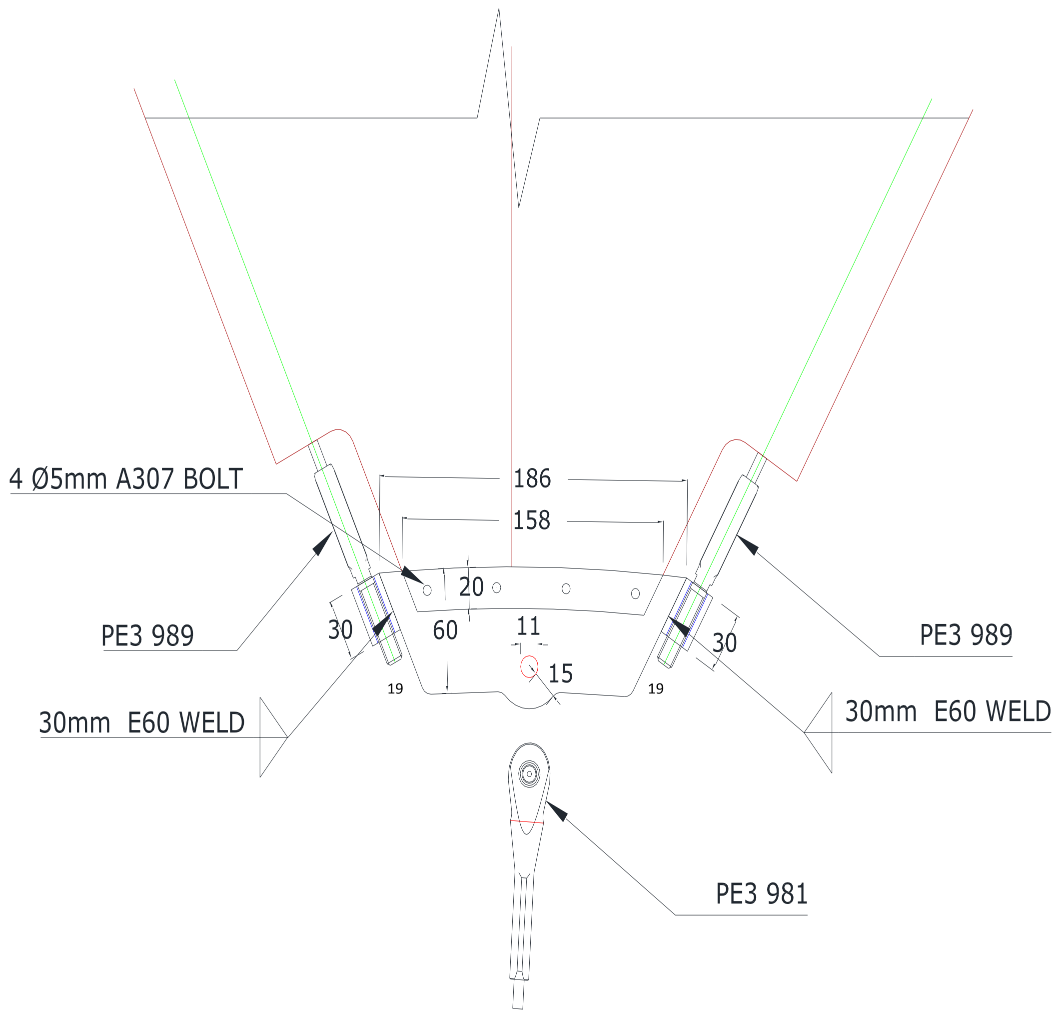


Plate size

Here

F_y=	24.5	KN/cm^2	For A36 steel
ϕ_b=	0.75		
l=	18.6	cm	
w=	0.06	KN/cm	for fabric
P=	12	KN	for edge cables

M_1= $wl^2/8$

= 2.59 KN-cm

M_2= Pl/4

= 55.80 KN-cm

M= M_1+M_2

= 58.39 KN-cm

Z= M/F_y

2.38 cm^3

Z= $bh^2/6$

Assume thichness of the plate 6mm

b= 0.6 cm

Then h= 4.88 cm Use 6cm Plate

Clamping plate size

F_y=	24.5	KN/cm^2
l=	4.2	cm
w=	0.06	KN/cm

M_n= $wl^2/8$

0.13 KN-cm

Z= M_n/F_y

0.0054 cm^3

Z= $bh^2/6$

Assume thichness of the plate 3mm

b= 0.3 cm

Then h= 0.33 cm

use 2 cm plate

Design of bolts in clamping plate

ϕ=	0.75		
F_v=	16.5	KN/cm^2	For A307 bolts
w=	0.06	KN/cm	
l=	15.8	cm	

R_b= $\phi * F_v * A_v$

Assume 3 bolts

Load on bolts=

wxl 0.9 KN

Load on each

bolts= 0.32 KN

Then

A_v= 0.03 cm^2

Required dia d= 0.18 cm

use 5mm bolts

Design of weld on arms Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= $0.6*F_{E60}$

Design strength per cm for .3cm of weld= $0.75*0.6*F_{E60}*0.707*0.3$

= 4.0 KN/cm

Load on weld= 6 KN

No. of weld= 2

Load per weld= 3 KN

Required weld length= 0.75 cm

use 3cm weld

Design of the tube for edge cable

Load= 6 KN

F_y= 24.5 KN/cm^2

Area required to resist A= 0.24 cm^2

Inner dia of the tube for cable end PE03 is 1.2 cm

Then, outer area- inner area= 0.48 cm^2

Thickness t= 0.12 cm

use 0.35cm thick tube

Design of the pin in double shear

ϕ= 0.75

F_u= 40 KN/cm^2 ultimate strength

Area in shear A_{sf}

Design load P_d= $\phi*0.6*F_u*A_{sf}$

Design load 12 KN

Then A_{sf}= $P_d/(\phi*0.6*F_u)$

= 0.67 cm^2

Area of the pin= 0.33 cm^2
Dia of the pin d= 0.65 cm
use .9cm pin PE 3

Design of the pin in bearing

ϕ= 0.75
F_y= 24.5 KN/cm^2 ultimate strength
Area in shear d_b*t
Design load P_d= ϕ*1.8* F_y* d_b*t
Design load 12 KN
d_b= 1.05 cm
Thickness t= 0.35 cm
use 0.6cm thick plate

Design of the plate in tension

ϕ= 0.75
F_u= 40 KN/cm^2
Thickeness t= 0.6 cm
Dia of pin d= 0.9 cm
Tension load = 12 KN
Tension load P_t= ϕ* F_v*A_e
Area in tension A_e= P_t/(ϕ* F_v)
= 0.4 cm^2
Gross Area A_g= A_e+(d+.15)*t
= 1.03 cm^2
Length in tension L_t= A_g/t
= 1.72 cm
Edge distance of the pin= 1.5*d
= 1.35 cm use 1.5cm
Edge distance on both side= 2.7 cm
2.7 > 1.72 OK

Design of the plate connecting cp01 with mast 01

Design of weld on arms Fillet type weld

ϕ= 0.75
F_{E60}= 42 KN/cm^2
F_w= 0.6*F_{E60}
Design strength per cm for .3cm of weld= 0.75*0.6*F_{E60}*0.707*0.3
= 4.0 KN/cm
Load on weld= 15 KN
No. of weld= 2
Load per weld= 7.5 KN
Required weld length= 1.87 cm
8cm weld will be provided

Design of the pin in double shear

ϕ= 0.75
F_u= 40 KN/cm^2 ultimate strength
Area in shear A_{sf}
Design load P_d= ϕ*0.6* F_u* A_{sf}
Design load 15 KN
Then A_{sf}= P_d/(ϕ*0.6* F_u)
= 0.83 cm^2
Area of the pin= 0.42 cm^2
Dia of the pin d= 0.73 cm
use 1.2cm pin PE 5

Design of the pin in bearing

ϕ= 0.75
F_y= 24.5 KN/cm^2 ultimate strength
Area in shear d_b*t
Design load P_d= ϕ*1.8* F_y* d_b*t
Design load 15 KN
d_b= 1.2 cm
Thickness t= 0.38 cm
use 0.6cm thick plate

Design of the plate in tension

ϕ= 0.75
F_u= 40 KN/cm^2
Thickeness t= 0.6 cm
Dia of pin d= 1.2 cm
Tension load = 15 KN
Tension load P_t= ϕ* F_v*A_e
Area in tension A_e= P_t/(ϕ* F_v)
= 0.5 cm^2
Gross Area A_g= A_e+(d+.15)*t

= 1.31 cm^2

Length in tension L_t= A_g/t

= 2.18 cm

Edge distance of the pin= 1.5*d

= 1.8 cm use 1.9 cm

Edge distance on both side= 3.6 cm

3.6 > 2.18 OK

Design of the plate connecting mast 01 and stay cable

Design of weld on arms Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= $0.6*F_{E60}$

Design strength per cm for .3cm of weld= $0.75*0.6*F_{E60}*0.707*0.3$

= 4.0 KN/cm

Load on weld= 10 KN

No. of weld= 2

Load per weld= 5 KN

Required weld length= 1.25 cm

7cm weld will be provided

Design of the pin in double shear

ϕ= 0.75

F_u= 40 KN/cm^2 ultimate strength

Area in shear A_{sf}

Design load P_d= $\phi*0.6*F_u*A_{sf}$

Design load 10 KN

Then A_{sf}= $P_d/(\phi*0.6*F_u)$

= 0.56 cm^2

Area of the pin= 0.28 cm^2

Dia of the pin d= 0.59 cm

use .9cm pin PE 3

Design of the pin in bearing

ϕ= 0.75

F_y= 24.5 KN/cm^2 ultimate strength

Area in shear d_b*t

Design load P_d= $\phi*1.8*F_y*d_b*t$

Design load 10 KN

d_b= 1.2 cm

Thickness t= 0.25 cm

use 0.6cm thick plate

Design of the plate in tension

ϕ= 0.75

F_u= 40 KN/cm^2

Thickeness t= 0.6 cm

Dia of pin d= 0.9 cm

Tension load = 10 KN

Tension load P_t= $\phi*F_v*A_e$

Area in tension A_e= $P_t/(\phi*F_v)$

= 0.333333 cm^2

Gross Area A_g= $A_e+(d+.15)*t$

= 0.963333 cm^2

Length in tension L_t= A_g/t

= 1.61 cm

Edge distance of the pin= 1.5*d

= 1.35 cm use 1.5 cm

Edge distance on both side= 2.7 cm

2.7 > 1.61 OK

Design of the bottom plate of mast 01

Design of weld Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= $0.6*F_{E60}$

Design strength per cm for .3cm of weld= $0.75*0.6*F_{E60}*0.707*0.3$

= 4.0 KN/cm

Load on weld= 23.05 KN

No. of weld= 2

Load per weld= 11.525 KN

Required weld length= 2.88 cm

8.9cm weld will be provided

Design of the pin in double shear

ϕ= 0.75

F_u= 40 KN/cm^2 ultimate strength

Area in shear A_{sf}

Design load P_d= $\phi*0.6*F_u*A_{sf}$

Design load 23.05 KN

Then A_{sf}= $P_d/(\phi*0.6*F_u)$
= 1.28 cm^2
Area of the pin= 0.64 cm^2
Dia of the pin d= 0.90 cm
use 1.2cm pin

Design of the pin in bearing
ϕ= 0.75
F_y= 24.5 KN/cm^2 ultimate strength
Area in shear d_b*t
Design load P_d= $\phi*1.8*F_y*d_b*t$
Design load 23.05 KN
d_b= 1.2 cm
Thickness t= 0.58 cm
use 0.8cm thick plate

Design of the plate in tension
ϕ= 0.75
F_u= 40 KN/cm^2
Thickeness t= 0.8 cm
Dia of pin d= 1.2 cm
Tension load = 23.05 KN
Tension load P_t= $\phi*F_v*A_e$
Area in tension A_e= $P_t/(\phi*F_v)$
= 0.768 cm^2
Gross Area A_g= A_e+(d+.15)*t
= 1.848 cm^2
Length in tension L_t= A_g/t
= 2.31 cm
Edge distance of the pin= 1.5*d
= 1.8 cm use 1.9 cm
Edge distance on both side= 3.6 cm
3.6 > 2.31 OK

Design of the anchorage plate for mast 01

Design of the pin in double shear
ϕ= 0.75
F_u= 40 KN/cm^2 ultimate strength
Area in shear A_{sf}
Design load P_d= $\phi*0.6*F_u*A_{sf}$
Design load 23.05 KN
Then A_{sf}= $P_d/(\phi*0.6*F_u)$
= 1.28 cm^2
Area of the pin= 0.64 cm^2
Dia of the pin d= 0.90 cm
use 1.2cm pin

Design of the pin in bearing
ϕ= 0.75
F_y= 24.5 KN/cm^2 ultimate strength
Area in shear d_b*t
Design load P_d= $\phi*1.8*F_y*d_b*t$
Design load 23.05 KN
d_b= 1.2 cm
Thickness t= 0.58 cm
Thickness of each plate t= 0.29 cm
use 0.6cm thick plate

Design of the plate in tension
ϕ= 0.75
F_u= 40 KN/cm^2
Thickeness t= 0.6 cm
Dia of pin d= 1.2 cm
Tension load = 23.05 KN
Tension load P_t= $\phi*F_v*A_e$
Area in tension A_e= $P_t/(\phi*F_v)$
= 0.768 cm^2
Gross Area A_g= A_e+(d+.15)*t
= 1.578 cm^2
Length in tension L_t= A_g/t
= 2.63 cm
Edge distance of the pin= 1.5*d
= 1.8 cm use 1.9 cm
Edge distance on both side= 3.6 cm
3.6 > 2.63 OK

Design of weld Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= 0.6*F_{E60}

Design strength per cm for .3cm of weld= 0.75*0.6*F_{E60}*0.707*0.3

= 4.0 KN/cm

Load on weld= 23.05 KN

No. of weld= 2

Load per weld= 11.525 KN

Required weld length= 2.88 cm

8.9cm weld will be provided

Design of the anchorage plate for mast 02

Design of the pin in double shear

ϕ= 0.75

F_u= 40 KN/cm^2 ultimate strength

Area in shear A_{sf}

Design load P_d= ϕ*0.6* F_u* A_{sf}

Design load 16.5 KN

Then A_{sf}= P_d/(ϕ*0.6* F_u)

= 0.92 cm^2

Area of the pin= 0.46 cm^2

Dia of the pin d= 0.76 cm

use 1.2cm pin

Design of the pin in bearing

ϕ= 0.75

F_y= 24.5 KN/cm^2 ultimate strength

Area in shear d_b*t

Design load P_d= ϕ*1.8* F_y* d_b*t

Design load 16.5 KN

d_b= 1.2 cm

Thickness t= 0.42 cm

Thickness of each plate t= 0.21 cm

use 0.6cm thick plate

Design of the plate in tension

ϕ= 0.75

F_u= 40 KN/cm^2

Thickeness t= 0.6 cm

Dia of pin d= 1.2 cm

Tension load = 23.05 KN

Tension load P_t= ϕ* F_v*A_e

Area in tension A_e= P_t/(ϕ* F_v)

= 0.768 cm^2

Gross Area A_g= A_e+(d+.15)*t

= 1.578 cm^2

Length in tension L_t= A_g/t

= 2.63 cm

Edge distance of the pin= 1.5*d

= 1.8 cm use 1.9 cm

Edge distance on both side= 3.6 cm

3.6 > 2.63 OK

Design of weld Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= 0.6*F_{E60}

Design strength per cm for .3cm of weld= 0.75*0.6*F_{E60}*0.707*0.3

= 4.0 KN/cm

Load on weld= 16.5 KN

No. of weld= 2

Load per weld= 8.25 KN

Required weld length= 2.06 cm

8.9cm weld will be provided

Design of the plate connecting corner plate 02 with mast 02

Design of weld on arms Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= 0.6*F_{E60}

Design strength per cm for .3cm of weld= 0.75*0.6*F_{E60}*0.707*0.3

= 4.0 KN/cm

Load on weld= 12 KN

No. of weld= 2
Load per weld= 6 KN
Required weld length= 1.50 cm
7cm weld will be provided

Design of the pin in double shear

ϕ= 0.75
F_u= 40 KN/cm^2 ultimate strength
Area in shear A_{sf}
Design load P_d= ϕ*0.6* F_u* A_{sf}
Design load 12 KN
Then A_{sf}= P_d/(ϕ*0.6* F_u)
= 0.67 cm^2
Area of the pin= 0.33 cm^2
Dia of the pin d= 0.65 cm
use .9cm pin PE 3

Design of the pin in bearing

ϕ= 0.75
F_y= 24.5 KN/cm^2 ultimate strength
Area in shear d_b*t
Design load P_d= ϕ*1.8* F_y* d_b*t
Design load 12 KN
d_b= 0.9 cm
Thickness t= 0.40 cm
use 0.6cm thick plate

Design of the plate in tension

ϕ= 0.75
F_u= 40 KN/cm^2
Thickeness t= 0.6 cm
Dia of pin d= 0.9 cm
Tension load = 12 KN
Tension load P_t= ϕ* F_v*A_e
Area in tension A_e= P_t/(ϕ* F_v)
= 0.4 cm^2
Gross Area A_g= A_e+(d+.15)*t
= 1.03 cm^2
Length in tension L_t= A_g/t
= 1.72 cm
Edge distance of the pin= 1.5*d
= 1.35 cm use 1.9 cm
Edge distance on both side= 2.7 cm
2.7 > 1.72 OK

Design of the plate connecting mast 02 and stay cable
Design of the pin in double shear

ϕ= 0.75
F_u= 40 KN/cm^2 ultimate strength
Area in shear A_{sf}
Design load P_d= ϕ*0.6* F_u* A_{sf}
Design load 11 KN
Then A_{sf}= P_d/(ϕ*0.6* F_u)
= 0.61 cm^2
Area of the pin= 0.31 cm^2
Dia of the pin d= 0.62 cm
use .9cm pin PE 3

Design of the pin in bearing

ϕ= 0.75
F_y= 24.5 KN/cm^2 ultimate strength
Area in shear d_b*t
Design load P_d= ϕ*1.8* F_y* d_b*t
Design load 11 KN
d_b= 1.2 cm
Thickness t= 0.28 cm
use 0.6cm thick plate

Design of the plate in tension

ϕ= 0.75
F_u= 40 KN/cm^2
Thickeness t= 0.6 cm
Dia of pin d= 0.9 cm
Tension load = 11 KN
Tension load P_t= ϕ* F_v*A_e
Area in tension A_e= P_t/(ϕ* F_v)
= 0.366667 cm^2
Gross Area A_g= A_e+(d+.15)*t
= 0.996667 cm^2
Length in tension L_t= A_g/t

= 1.66 cm

Edge distance of the pin= 1.5*d

= 1.35 cm use 1.5 cm

Edge distance on both side= 2.7 cm

2.7 > 1.66 OK

Design of weld on arms Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= 0.6*F_{E60}

Design strength per cm for .3cm of weld= 0.75*0.6*F_{E60}*0.707*0.3

= 4.0 KN/cm

Load on weld= 11 KN

No. of weld= 2

Load per weld= 5.5 KN

Required weld length= 1.37 cm

8cm weld will be provided

Design of the bottom plate of mast 02

Design of the pin in double shear

ϕ= 0.75

F_u= 40 KN/cm^2 ultimate strength

Area in shear A_{sf}

Design load P_d= ϕ*0.6* F_u* A_{sf}

Design load 16.5 KN

Then A_{sf}= P_d/(ϕ*0.6* F_u)

= 0.92 cm^2

Area of the pin= 0.46 cm^2

Dia of the pin d= 0.76 cm

use 1.2cm pin

Design of the pin in bearing

ϕ= 0.75

F_y= 24.5 KN/cm^2 ultimate strength

Area in shear d_b*t

Design load P_d= ϕ*1.8* F_y* d_b*t

Design load 16.5 KN

d_b= 1.2 cm

Thickness t= 0.42 cm

use 0.8cm thick plate

Design of the plate in tension

ϕ= 0.75

F_u= 40 KN/cm^2

Thickeness t= 0.8 cm

Dia of pin d= 1.2 cm

Tension load = 23.05 KN OK

Tension load P_t= ϕ* F_v*A_e

Area in tension A_e= P_t/(ϕ* F_v)

= 0.768 cm^2

Gross Area A_g= A_e+(d+.15)*t

= 1.848 cm^2

Length in tension L_t= A_g/t

= 2.31 cm

Edge distance of the pin= 1.5*d

= 1.8 cm use 1.9 cm

Edge distance on both side= 3.6 cm

3.6 > 2.31

Design of weld Fillet type weld

ϕ= 0.75

F_{E60}= 42 KN/cm^2

F_w= 0.6*F_{E60}

Design strength per cm for .3cm of weld= 0.75*0.6*F_{E60}*0.707*0.3

= 4.0 KN/cm

Load on weld= 16.5 KN

No. of weld= 2

Load per weld= 8.25 KN

Required weld length= 2.06 cm

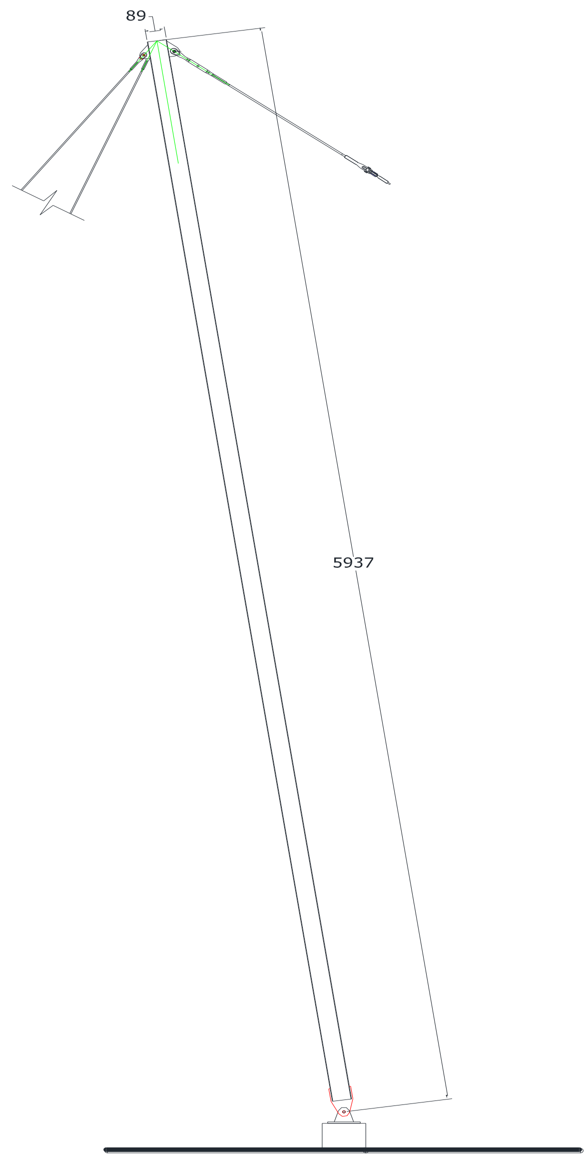
7cm weld will be provided

Design of Masts M01

Forces F= 23.05 KN
Length L= 600cm
Section Property Dia 89.1mm, Thk 2.5mm
Material A53 grade B(pipe)

Gross Area A_g= 6.79cm^2
Moment of Inertia I= 63.37cm^4
Radius of Gyration r= 3.06cm

K= 1
KL/r= 196.34
Slenderness parameter λ_c = (KL/rπ)xSqrt(F_y/E)
= 2.138364 (F_y= 24KN/cm^2, E= 20500KN/cm^2)
Since, λ_c>1.5
Then, Critical Stress F_{cr} material side = (0.877/ λ_c^2)F_y
= 4.6 KN/cm^2
Resistance factor ϕ_c = 0.85
Design Strength P_n= A_g F_{cr}
= 32.23 KN
Factored Strength ϕ_c P_n = 26.54KN > 23.05 KN   OK



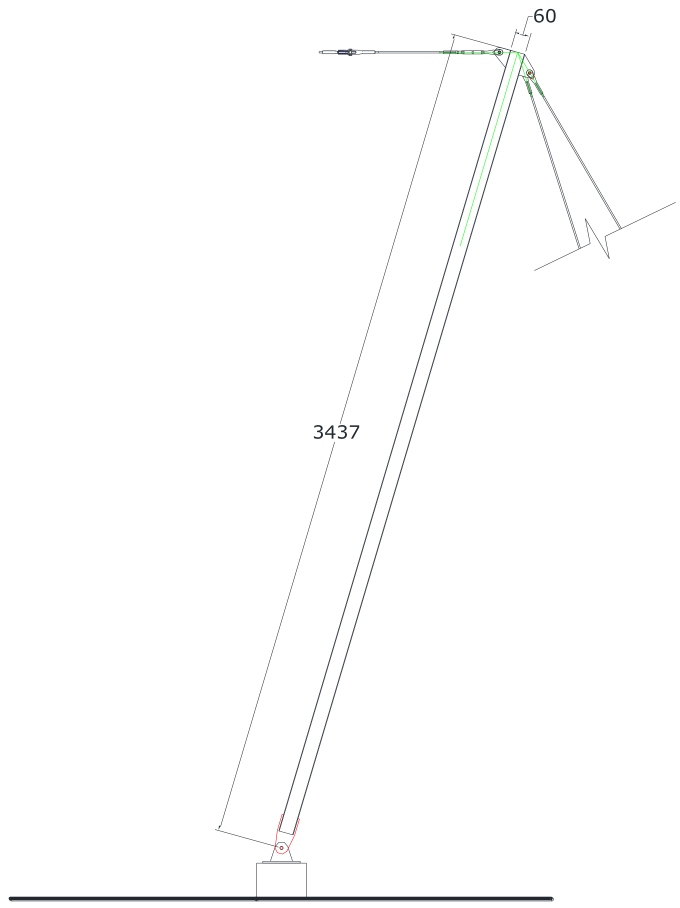
Mast01

Design of Masts M02

Forces F= 16.46 KN
Length L= 350cm
Section Property Dia 60.3mm, Thk 2mm
Material A53 grade B(pipe)

Gross Area A_g= 3.66cm^2
Moment of Inertia I= 15.58cm^4
Radius of Gyration r= 2.06cm

K= 1
KL/r= 169.7
Slenderness parameter λ_c = (KL/rπ)xSqrt(F_y/E)
= 1.848289 (F_y= 24KN/cm^2, E= 20500KN/cm^2)
Since, λ_c>1.5
Then, Critical Stress F_{cr} material side = (0.877/ λ_c^2)F_y
= 6.16 KN/cm^2
Resistance factor ϕ_c = 0.85
Design Strength P_n= A_g F_{cr}
= 22.57 KN
Factored Strength ϕ_c P_n = 19.18KN > 16.46 KN   OK



Mast02

Uplift resistance capacity of the Foundation

Unit weight of soil (fill) and concrete=	19.6375	KN/m3
Pressure of this material at 80cm=	15.71	KN/m2
	0.001571	KN/cm2
Assume allowable soil pressure=	3.45	KN/cm2
Available bearing pressure=	3.44843	KN/cm2
Load on footing=	23.05	KN
Required area for footing=	6.6842	cm2
A footing base 76x76cm2 is provided		