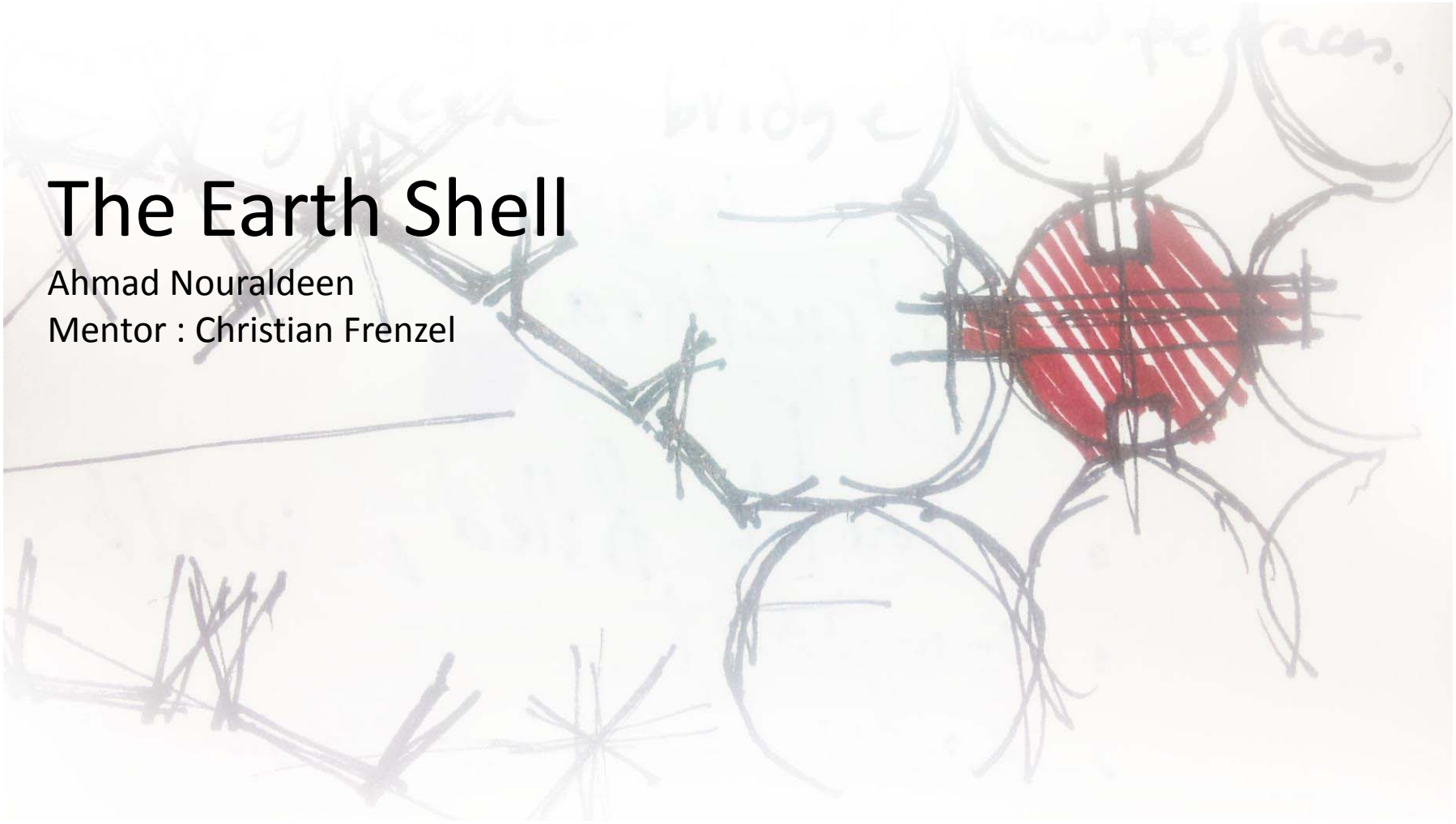
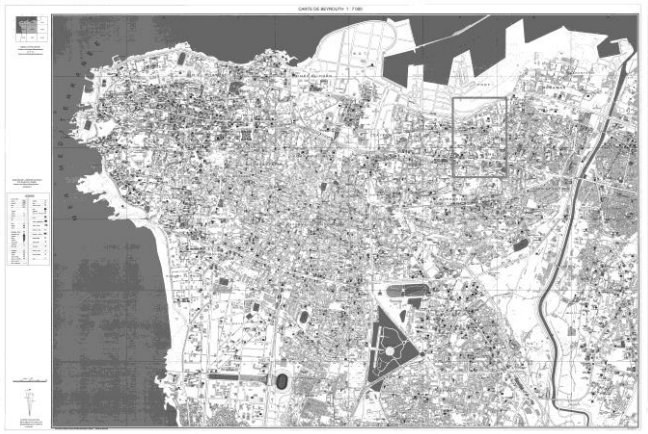
The Earth Shell

Ahmad Nouraldeen
Mentor : Christian Frenzel



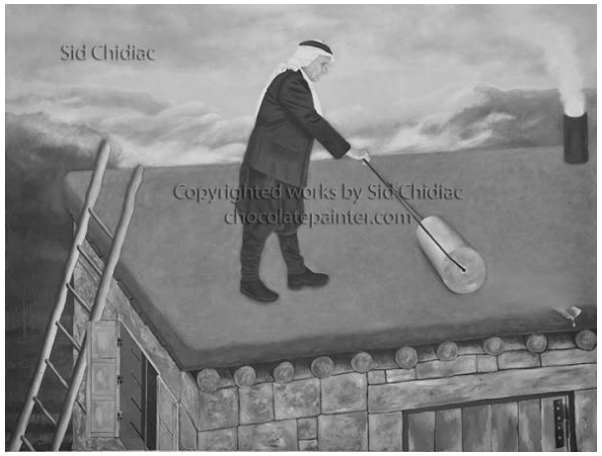
The lack of green space in the city and the lack of space to create green spaces render a gloomy city. “The Earth Shell” shall be adaptive in form and use, easy to assemble and disassemble, modular, light-weight and compact, making it feasible as a do-it-yourself project for any building resident and applied on any roof.



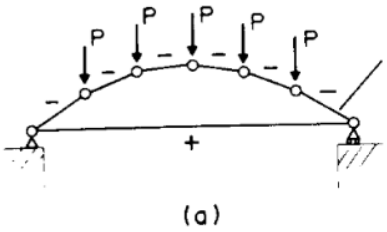
50 years ago

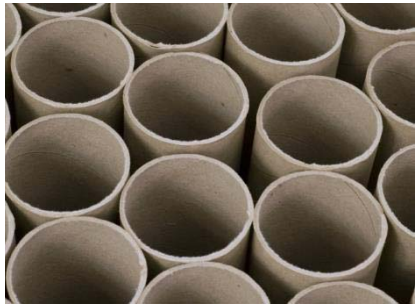
HISTORICAL INSPIRATION

Traditional Lebanese Sand Roofs



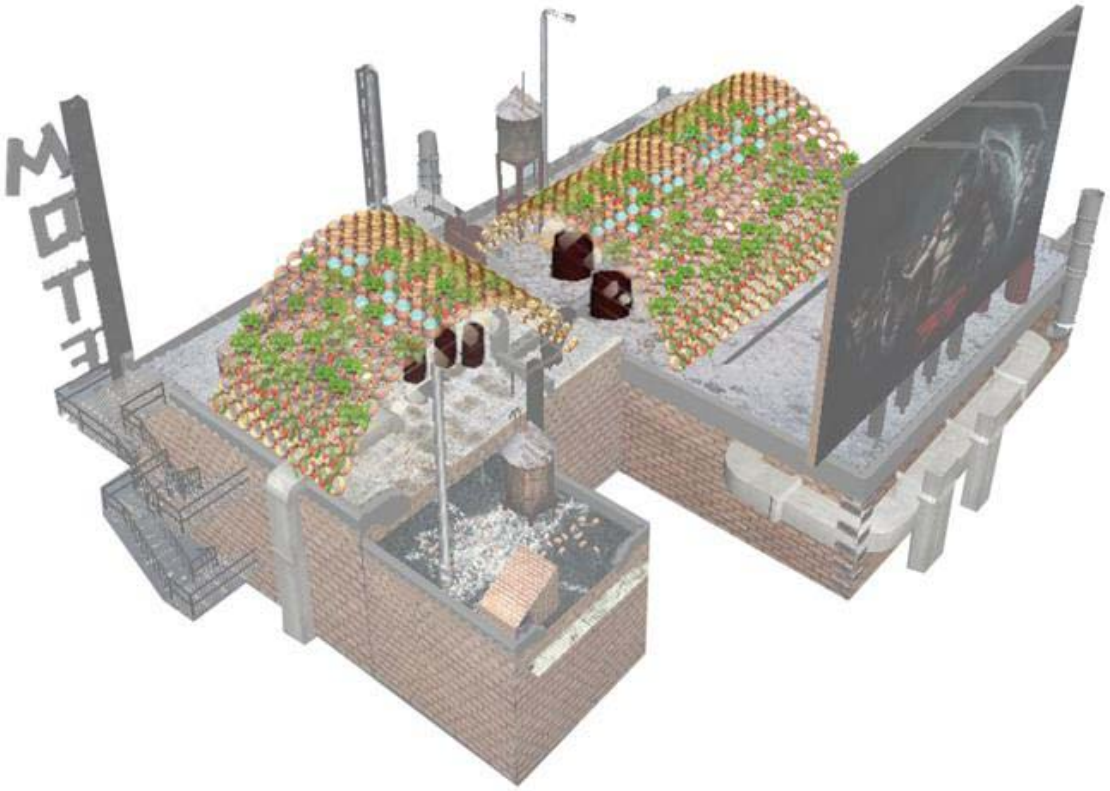
Traditional Cross Vault





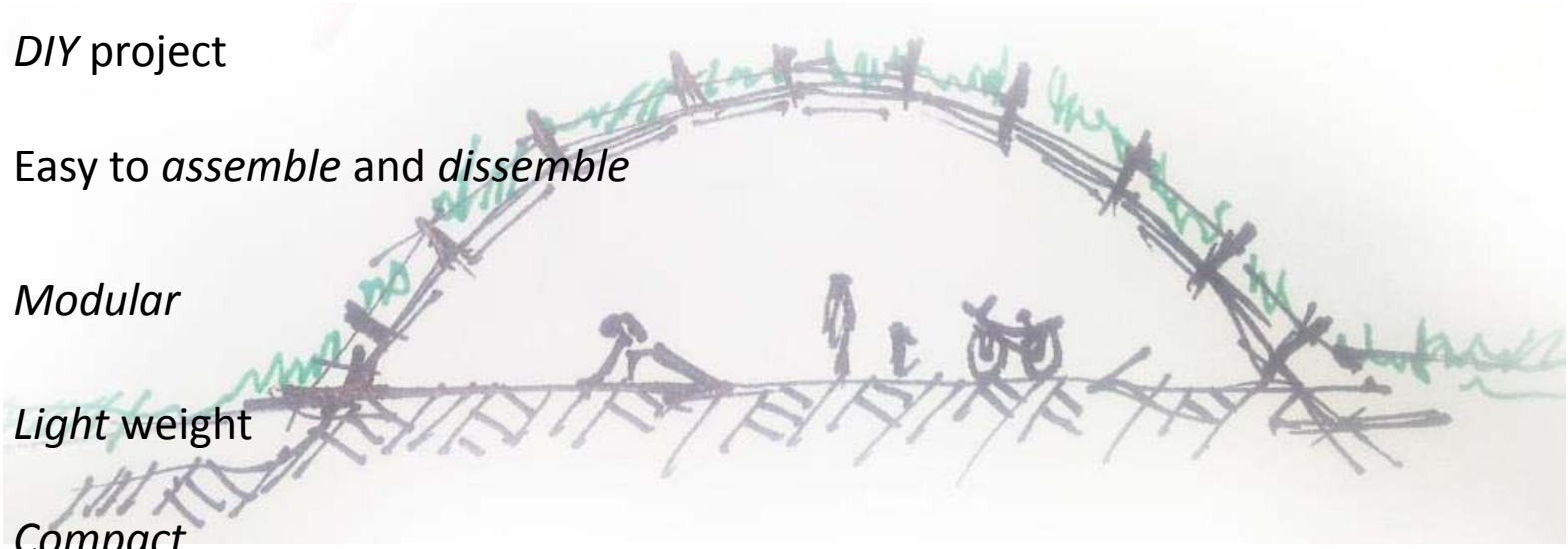
VISION

Construct a simple and cost effective canopy that will cover existing roof with green.



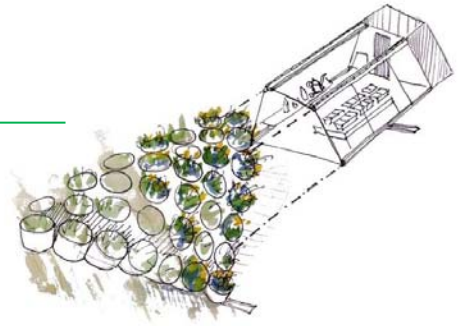
CHARACTERISTICS

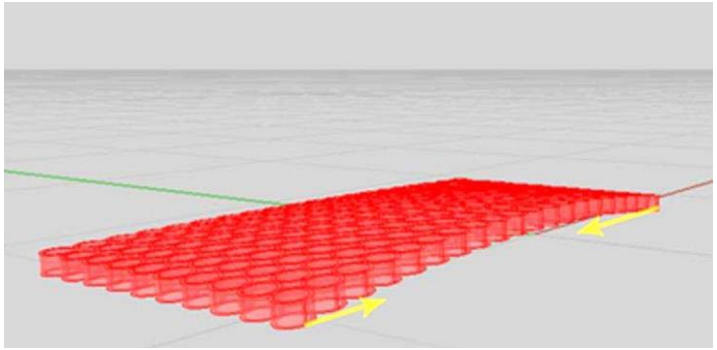
- Adaptive in *scale*, *form*, and *use*
- *DIY* project
- Easy to *assemble* and *dissemble*
- *Modular*
- *Light* weight
- *Compact*



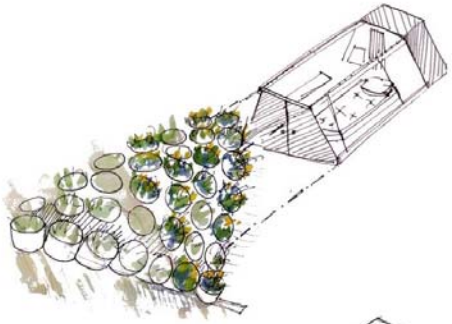
Multiple Configurations

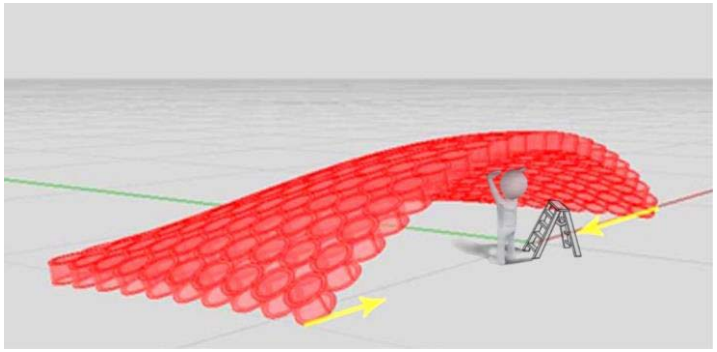
A Living Market



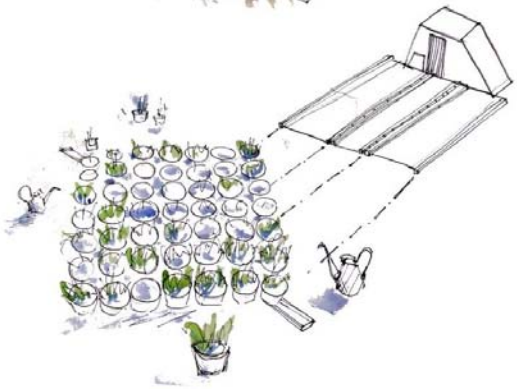


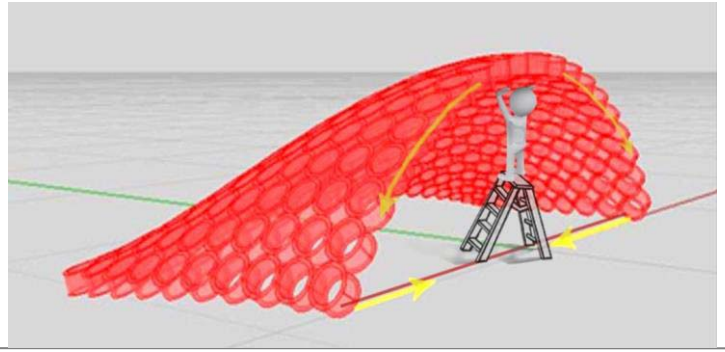
A Living Roof habitat



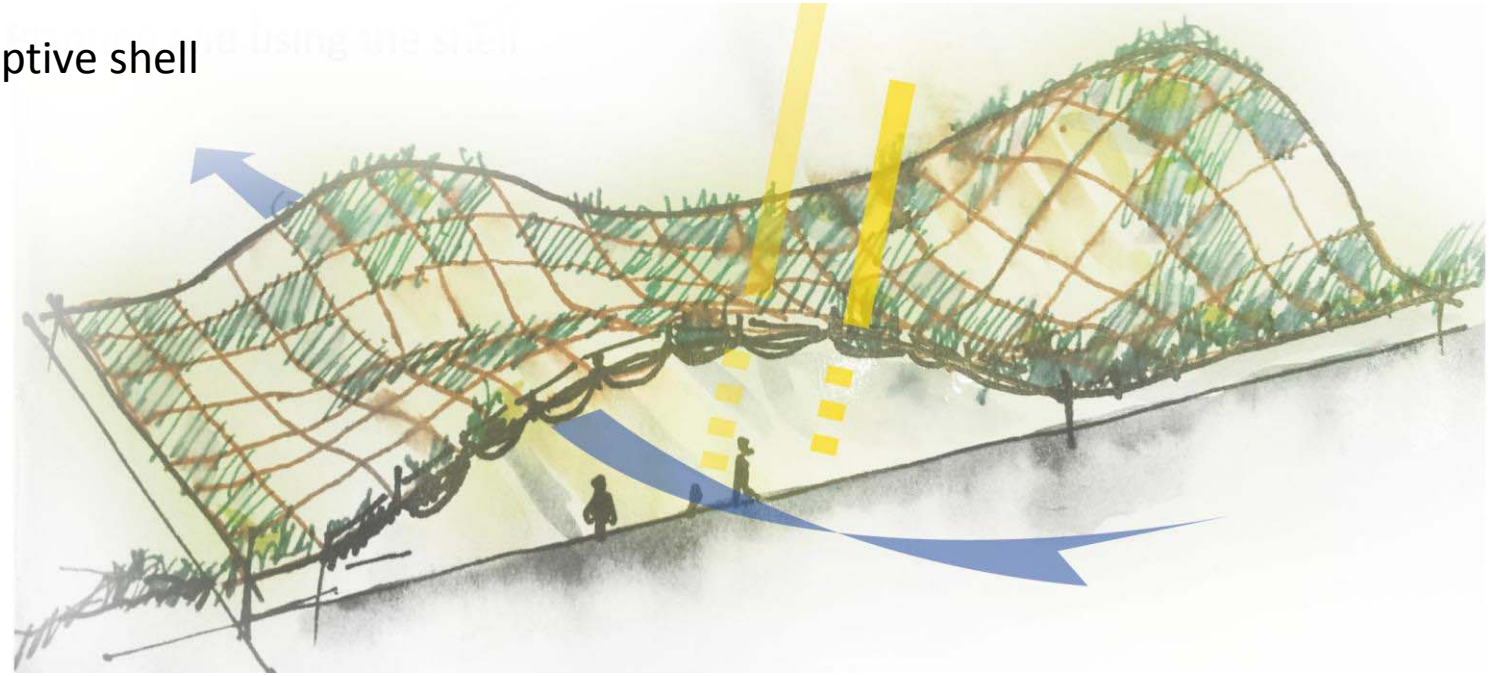


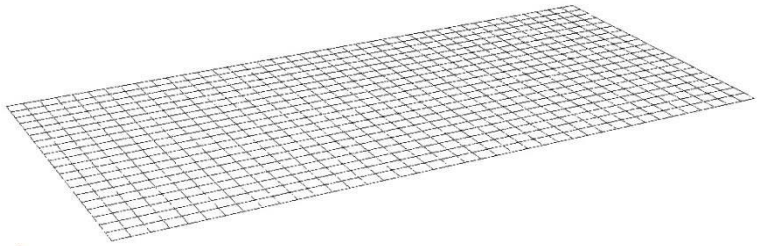
Unfolding

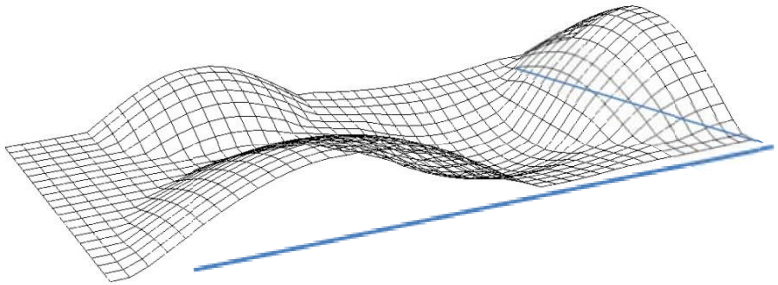




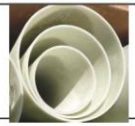
The adaptive shell







MATERIALS

Cardboard Tubes	Clay/Ceramic Tubes	Fiberglass Tubes	Plastic/PVC Tubes
			
Recyclable from paper material. biodegradable	Recyclable from earth material. biodegradable	advanced level of production	Needs more energy in production
easily produced for different sizes	needs special production and treatment	high tech fabrication	easily produced for different sizes
cheap, 2 dollar per module	costly , 25 dollar per module	too costly, 70 dollar per module	cheap relatively, 6 dollar per module
Can be thickened for high compresion strenght	induces sudden failure after certain amount of pressure	perfect structural characteristics	available for different thickness
Should be treated for water proofing	waterproof	weather and climate proof	weather and climate proof
lasts up to 2 years , depending on locution and treatment	can last up to 15 years up to maintenance	no life-time limit	can last up to 15 years up to maintenance

MATERIALS

The core of this project relies on the use of **PVC** pipes. PVC has high hardness and mechanical properties and is relatively cost efficient.

The mechanical properties improve with increasing molecular weight, but decrease with an increase in temperature.

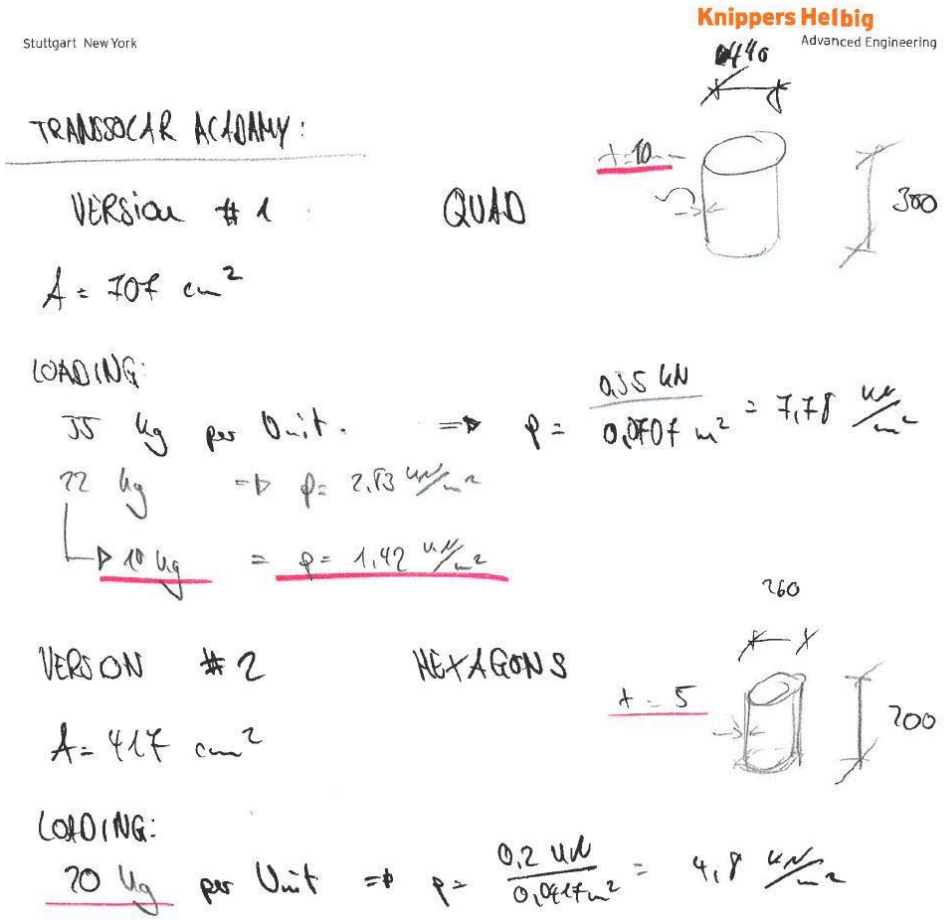
The elastic modulus of rigid PVC (uPVC) can reach to 1500-3,000 MPa.

The soft PVC (Flexible PVC) elastic modulus is 1.5-15 MPa.

The elongation at breaking point is up to 200% -450%.

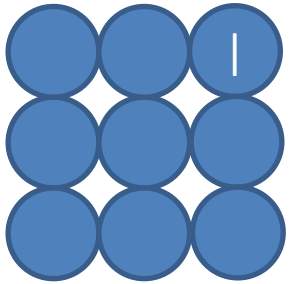
The static friction factor is 0.4-0.5, the dynamic friction factor is 0.23.

Structural analysis



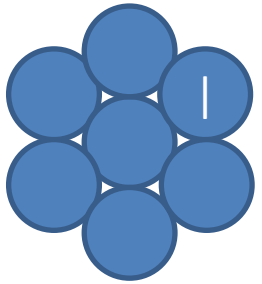
Quad

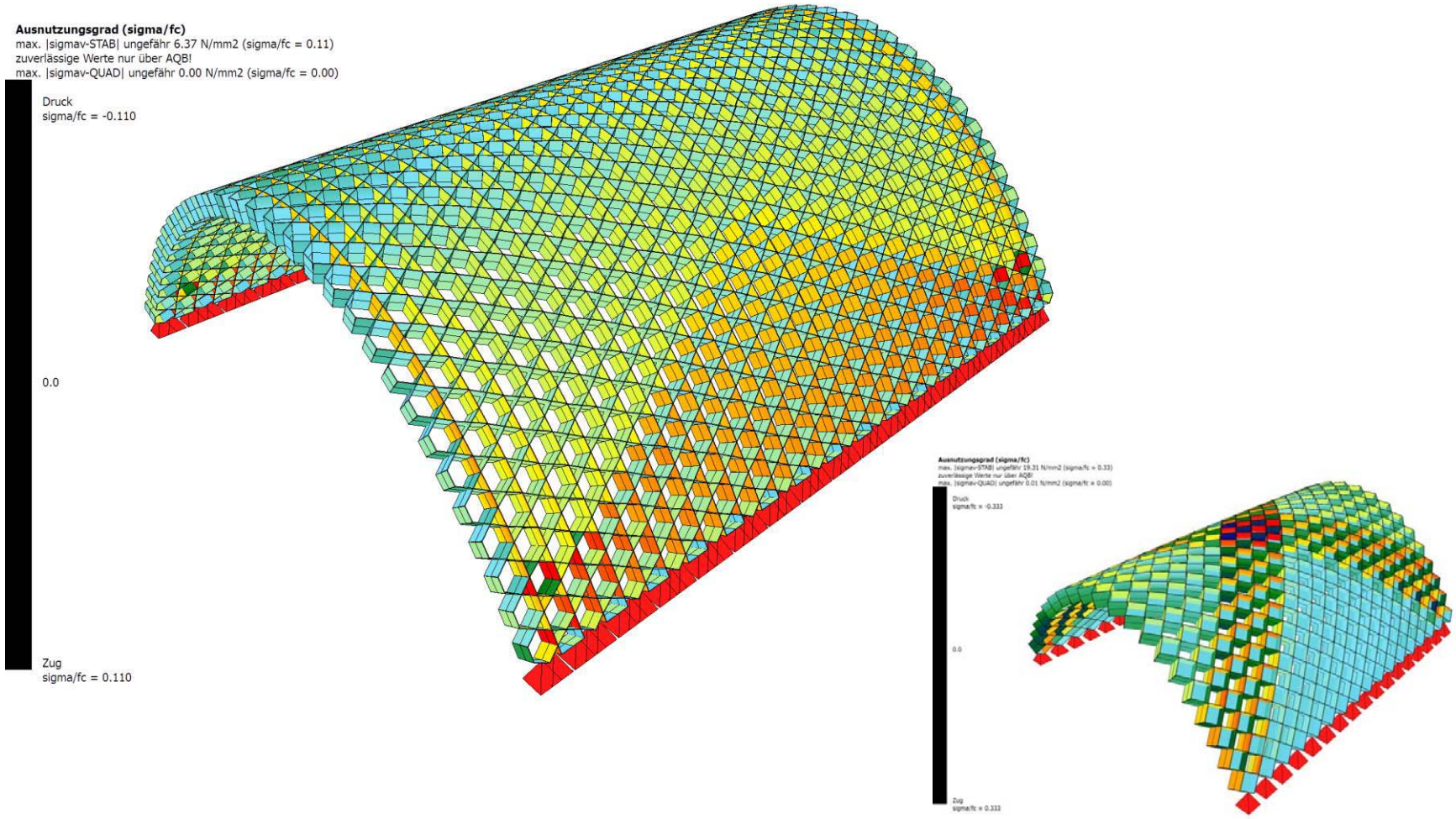
- max weight is 55 Kg per unit
- 20 units per arch
- Unit cylinder diameter is 44 cm
- Depth of cylinder can range 20 to 35 cm
- Or PVC pipes thickness 0.5 cm
- Optional to decrease weight on stressed areas (leave it empty)



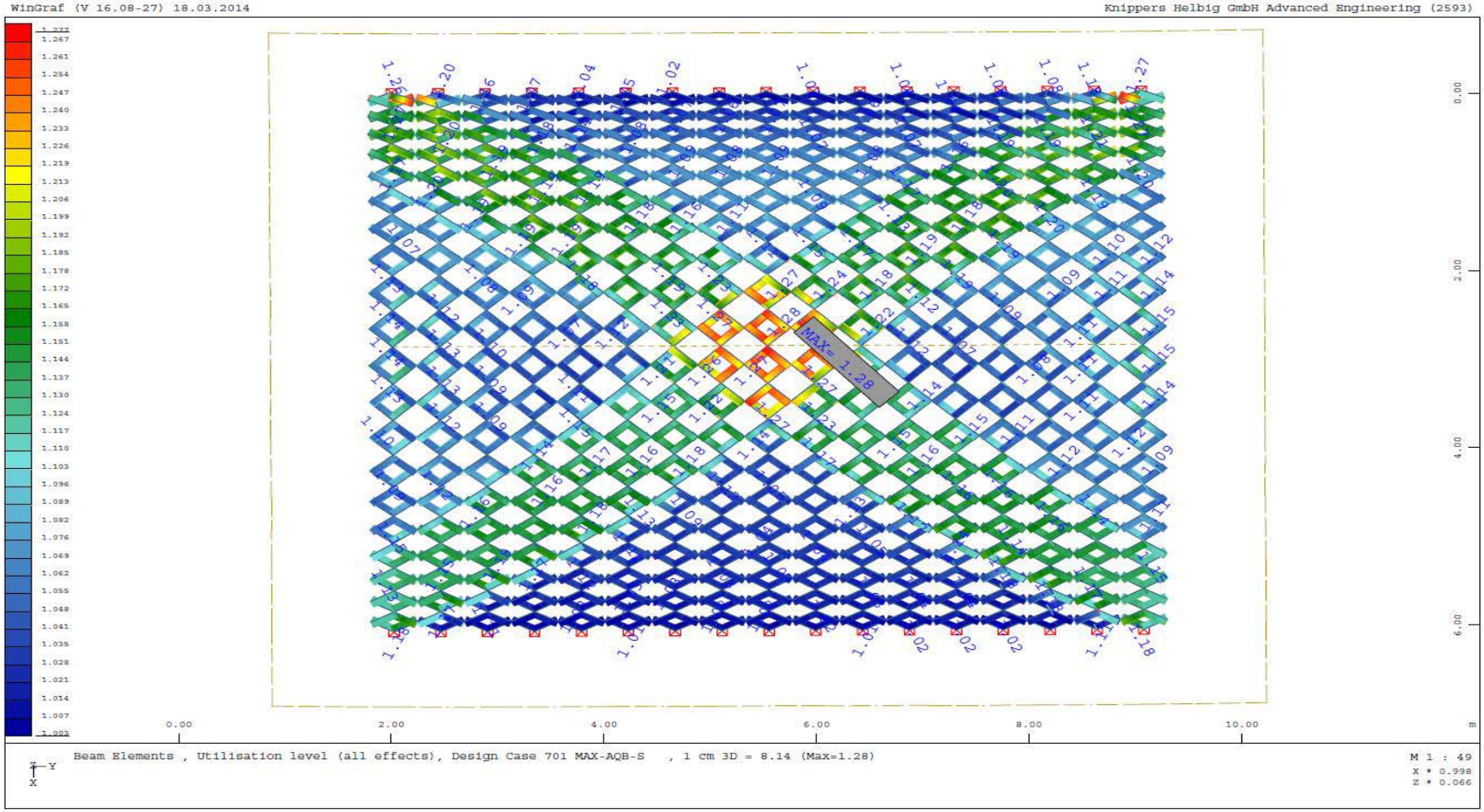
Hexa

- max weight is 20 Kg per unit
- 30 units per arch
- Unit cylinder diameter is 26 cm
- Depth of cylinder can range 15 to 25 cm
- PVC pipes thickness 0.5 cm
- Optional to decrease weight on stressed areas (leave it empty)




Ausnutzungsgrad (sigma/fc)
max. |sigmav-STAB| ungefähr 6.37 N/mm2 (sigma/fc = 0.11)
zuverlässige Werte nur über AQB!
max. |sigmav-QUAD| ungefähr 0.00 N/mm2 (sigma/fc = 0.00)
Druck
sigma/fc = -0.110
0.0
Zug
sigma/fc = 0.110
Ausnutzungsgrad (sigma/fc)
max. |sigmav-STAB| ungefähr 19.31 N/mm2 (sigma/fc = 0.33)
zuverlässige Werte nur über AQB!
max. |sigmav-QUAD| ungefähr 0.01 N/mm2 (sigma/fc = 0.00)
Druck
sigma/fc = -0.333
0.0
Zug
sigma/fc = 0.333

Utilization Level in Octagonal



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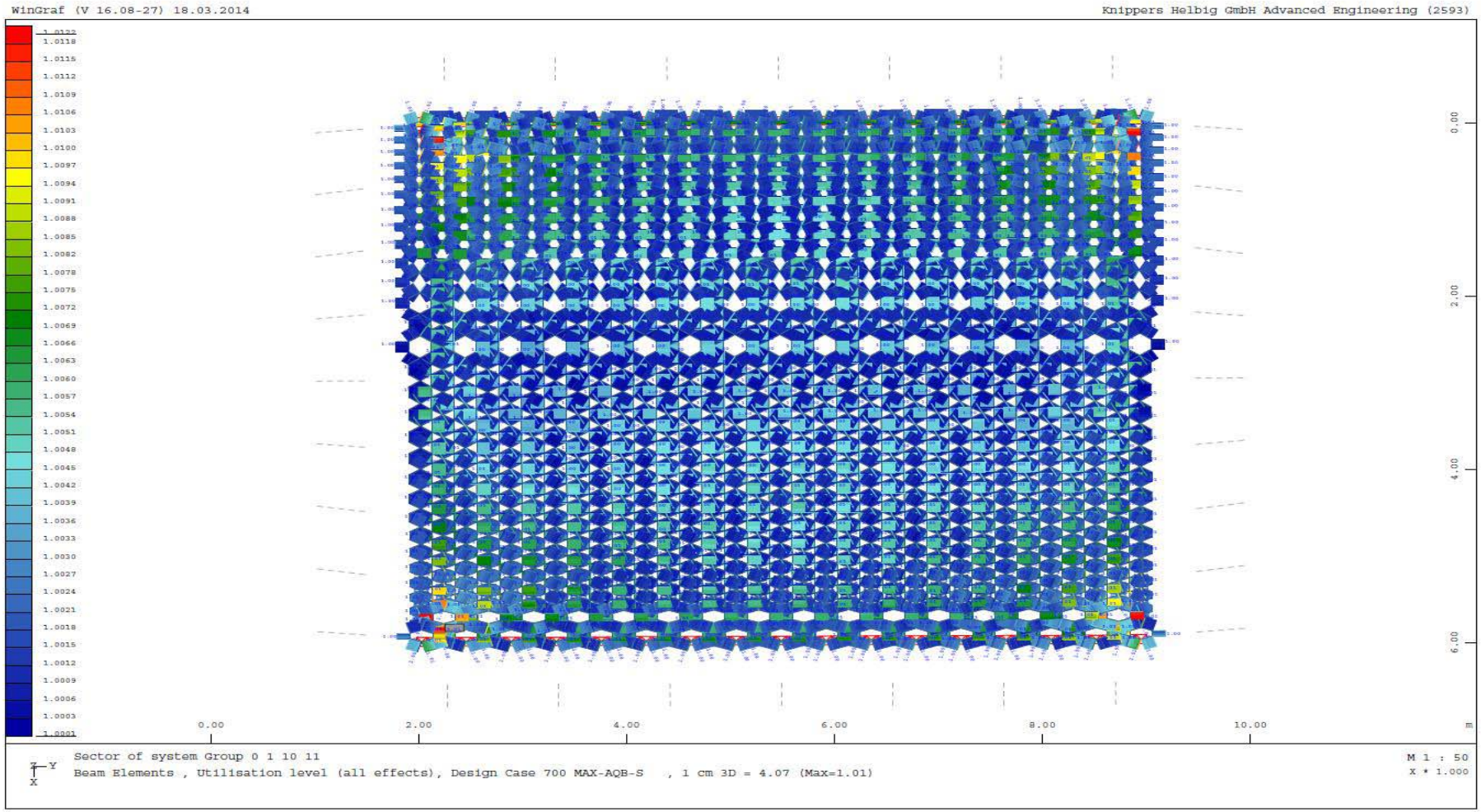
Utilization Level in Hexagonal



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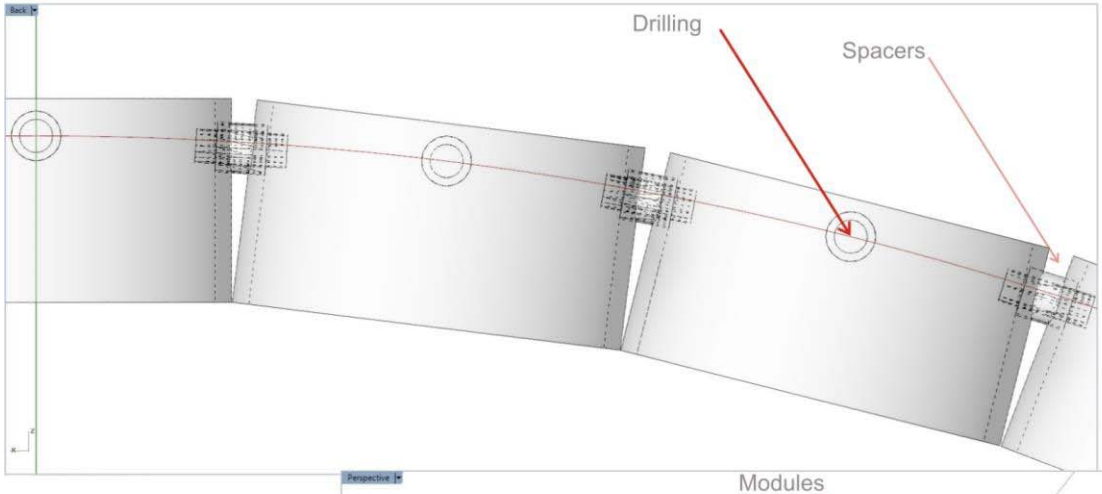
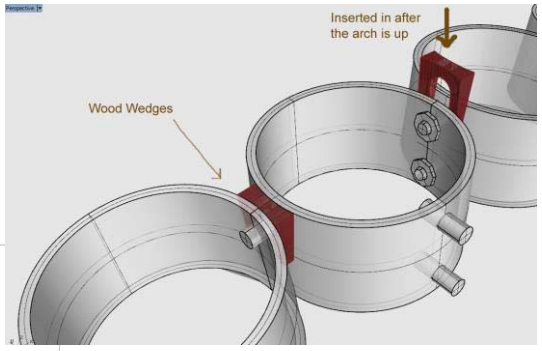
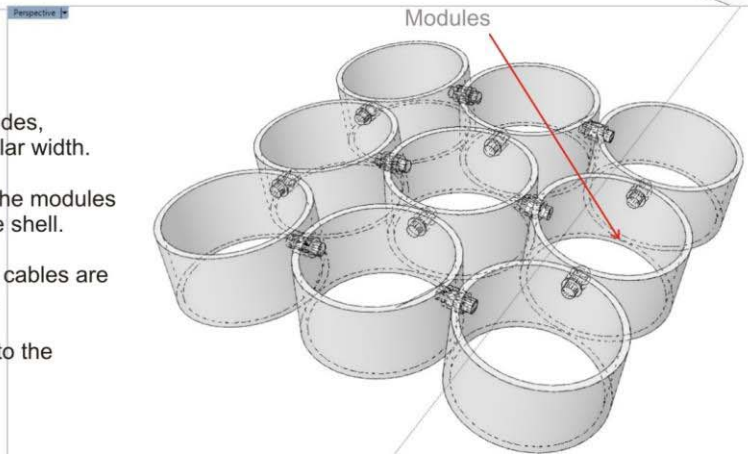
Detailing Study

Module Connections

The Detailing of project combines the modules to act as one coherent fabric.







The modules are drilled in four sides, and connected by screws of similar width.

A spacer is inserted in between the modules to get a specific curvatures of the shell.

At the final curvature the tension cables are locked in place, as a pretension.

After that weight can be applied to the shell.

Time to try a scaled model!!

Village House

Compact modules as planting pods
Connected with screws to each other
160 pods was used

Implementation and modules

Connecting the pods to become a shell

Simple connections used between the pods

Simply constructed and attached

Transportation to the site


WANT MY

Rope used as a spacer to get the desired curve from the shell

Rope used as a spacer to get the desired curve from the shell

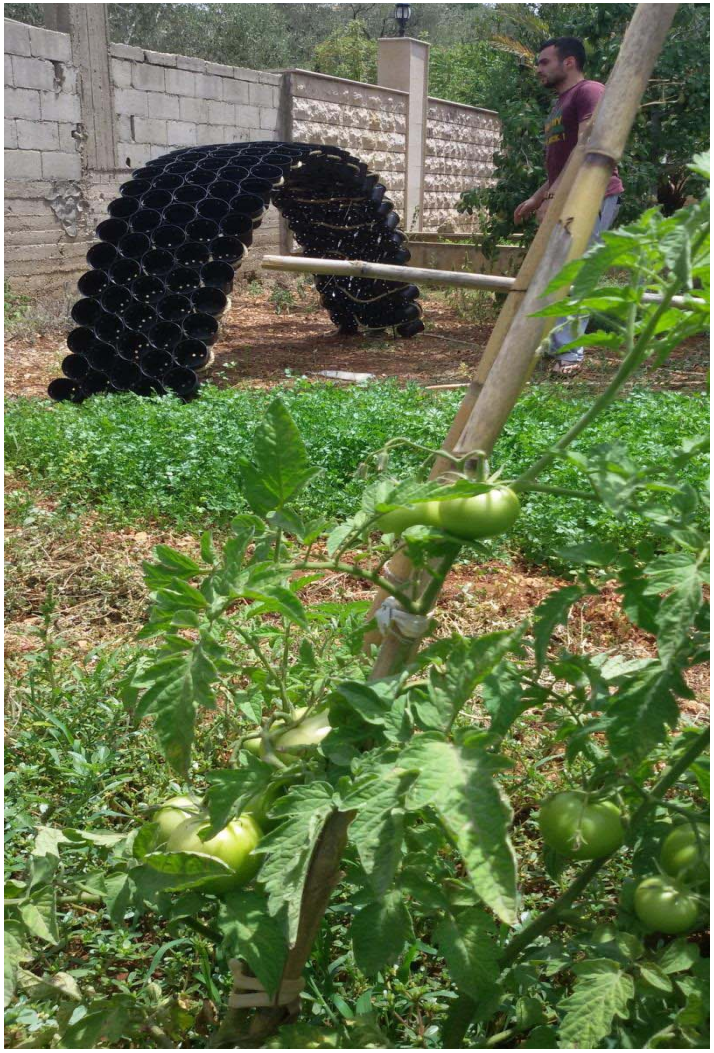
Light weight parts

6 kg for this piece

Mock-up scale ½

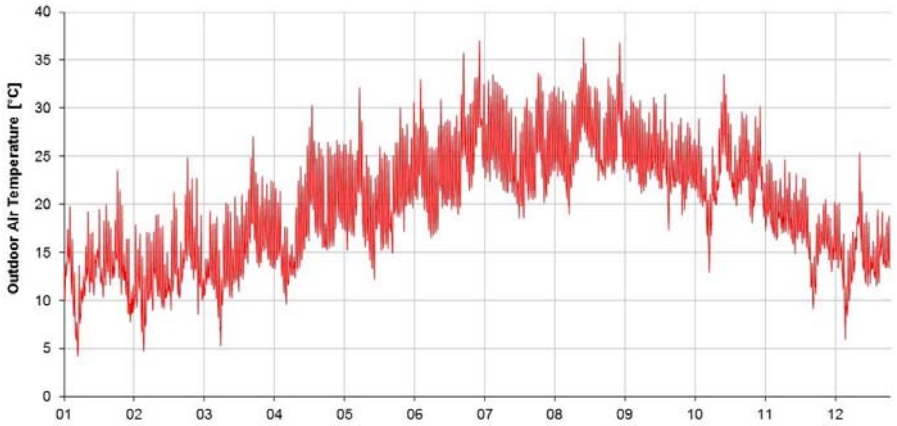

I WANT MY
ANET BACK

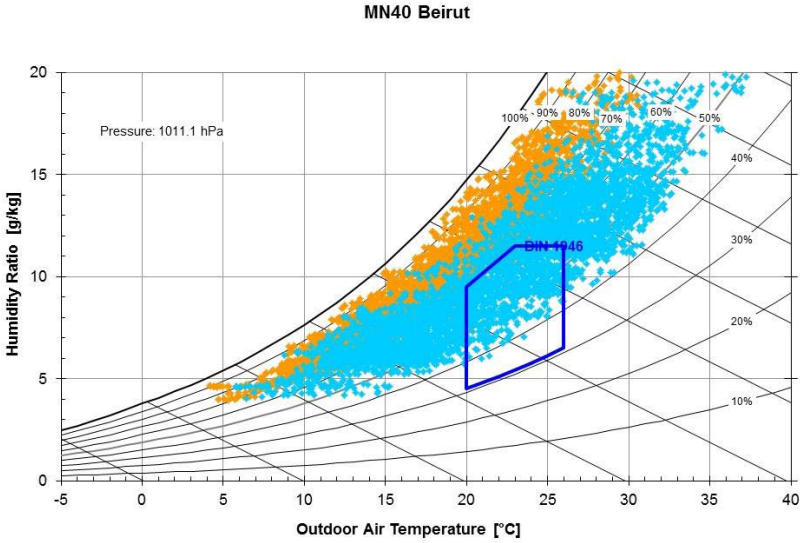
Ready to be planted!



A Climate Responsive Shell!

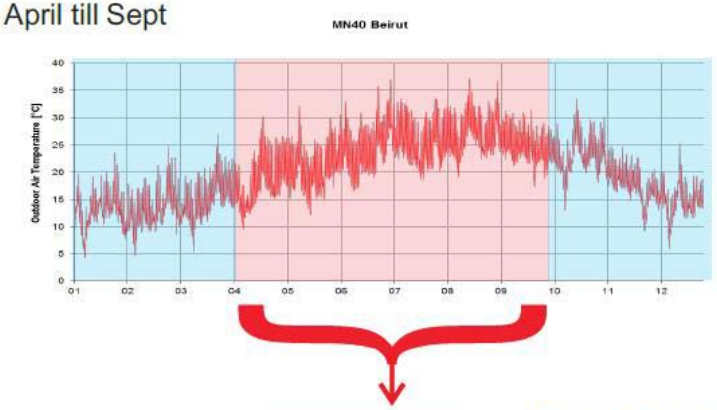
Beirut Climate MN40 Beirut





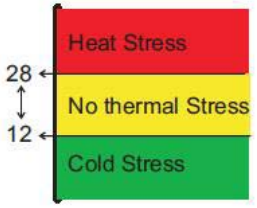
Outdoor Analysis for the **Hot Section**

April till Sept



Base Case 1

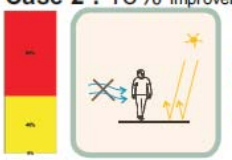
0.9 coefficient of solar absorption (black ground
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling



Outdoor Analysis for the **Hot Section**

April till Sept

Case 2 : 13% improvement



Case 2

0.2 coefficient of solar absorptions (white ground)
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling

Case 3 : 12% improvement

Case 3

0.9 coefficient of solar absorptions (black ground)
0.7 wind factor (normal wind)
no membrane
no adiabatic cooling

Case 4 : 20% improvement

Case 4

0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
with membrane (in shade)
no adiabatic cooling

Case 5 : 20% improvement

Case 5

0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
no membrane
adiabatic cooling on(plants of 0.25 humidity on 26 degrees on)

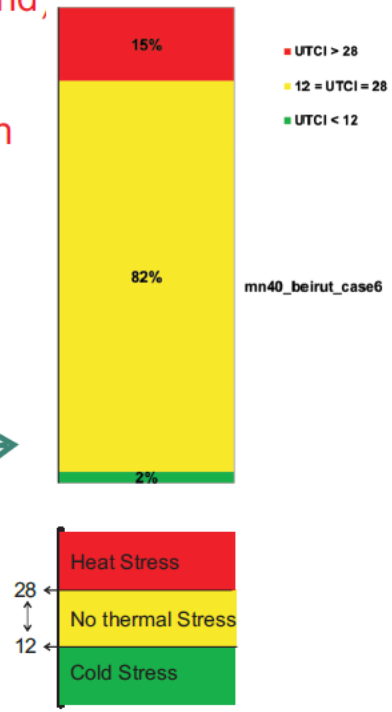
Outdoor Analysis for the **Hot Section**

April till Sept

Case 6 : 55% improvement

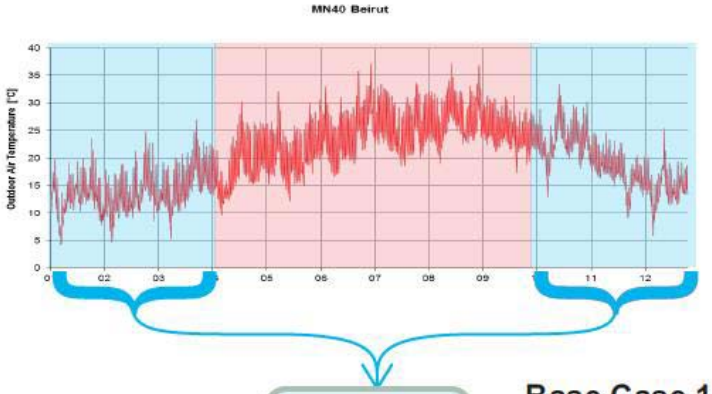
Case 6 all

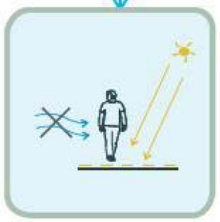
0.2 coefficient of solar absorptions (white ground)
0.7 wind factor (with wind)
with membrane (shaded)
adiabatic cooling on(plants of 0.25 humidity on 26 degrees on)



Outdoor Analysis for the **Cold Section**

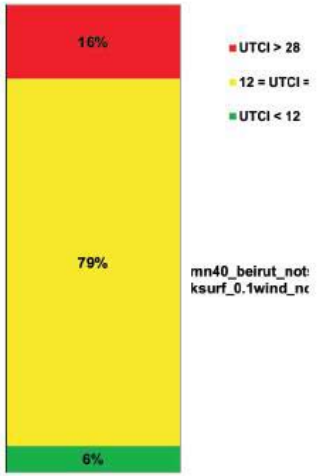
April till Sept

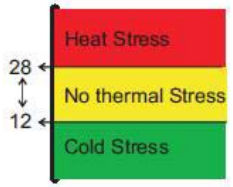




Base Case 1

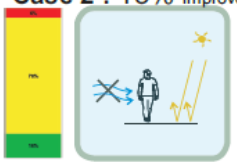
0.9 coefficient of SA (black ground)
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling





Outdoor Analysis for the Cold Section

Case 2 : 13% improvement



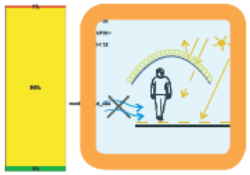
Case 2

0.2 coefficient of solar absorptions (white ground)
0.1 wind factor (almost no wind)
no membrane
no adiabatic cooling

Case 3 : 12% improvement

Case 3

0.9 coefficient of solar absorptions (black ground)
0.7 wind factor (normal wind)
no membrane
no adiabatic cooling



Case 4

0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
with membrane (in shade)
no adiabatic cooling

Case 5 : 20% improvement

Case 5

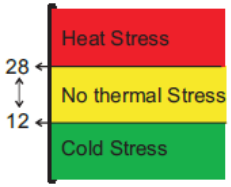
0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
no membrane
adiabatic cooling on(plants of 0.25 humidity on 26 degrees on)

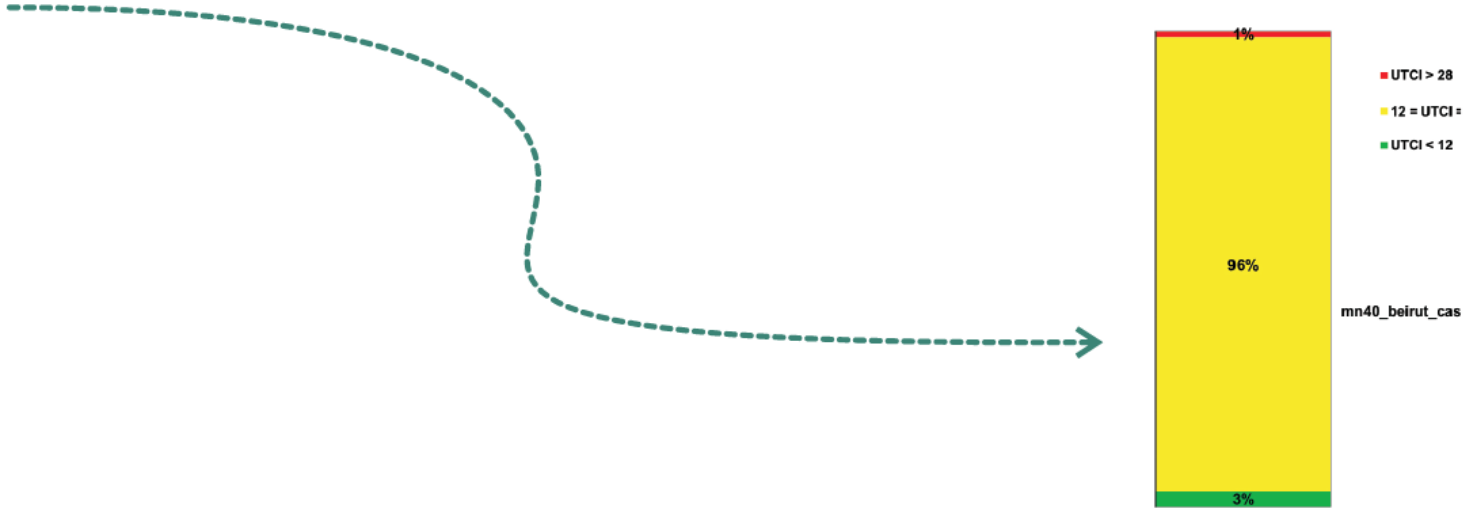
Outdoor Analysis for the Cold Section

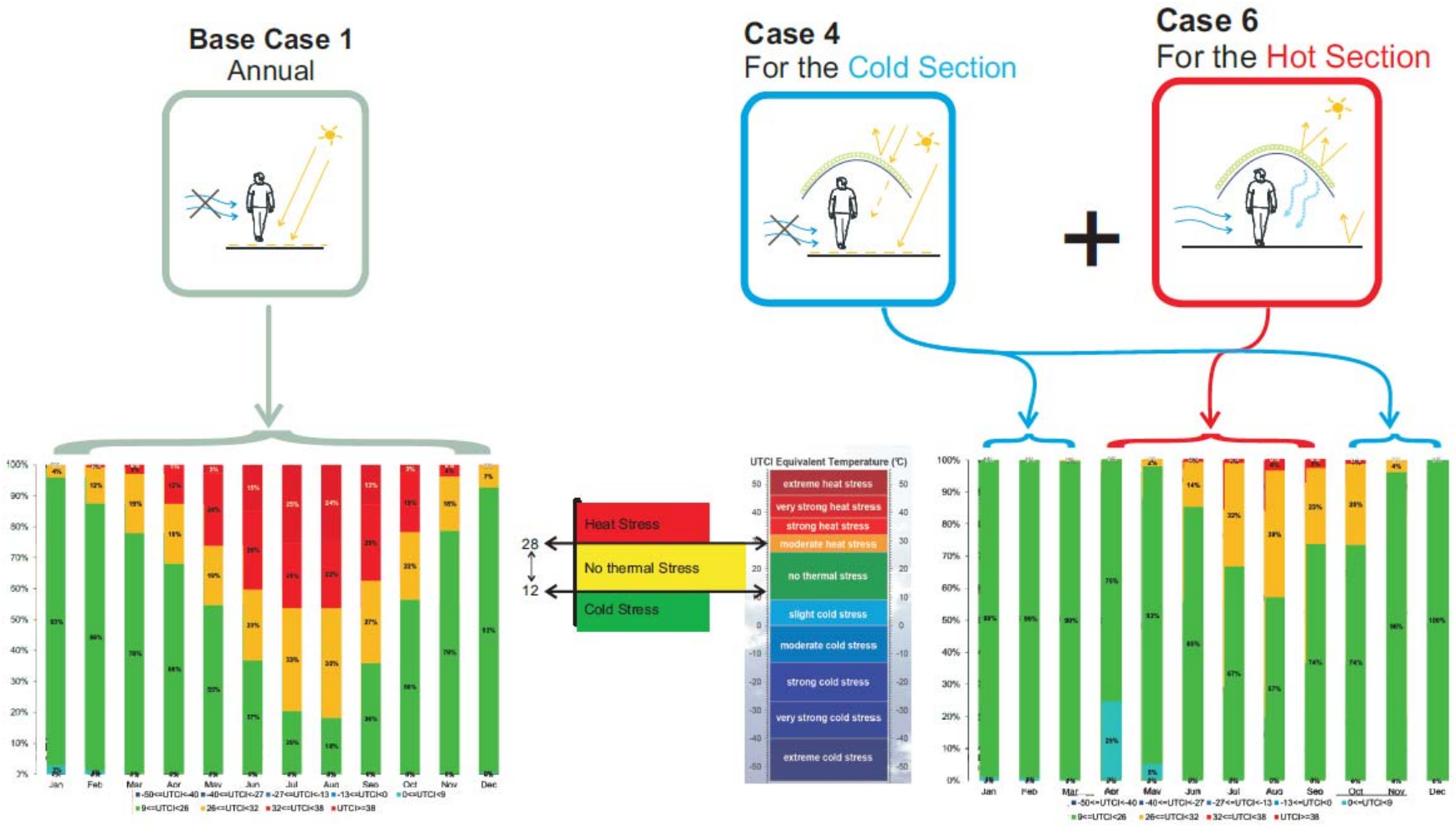
April till Sept

Case 4

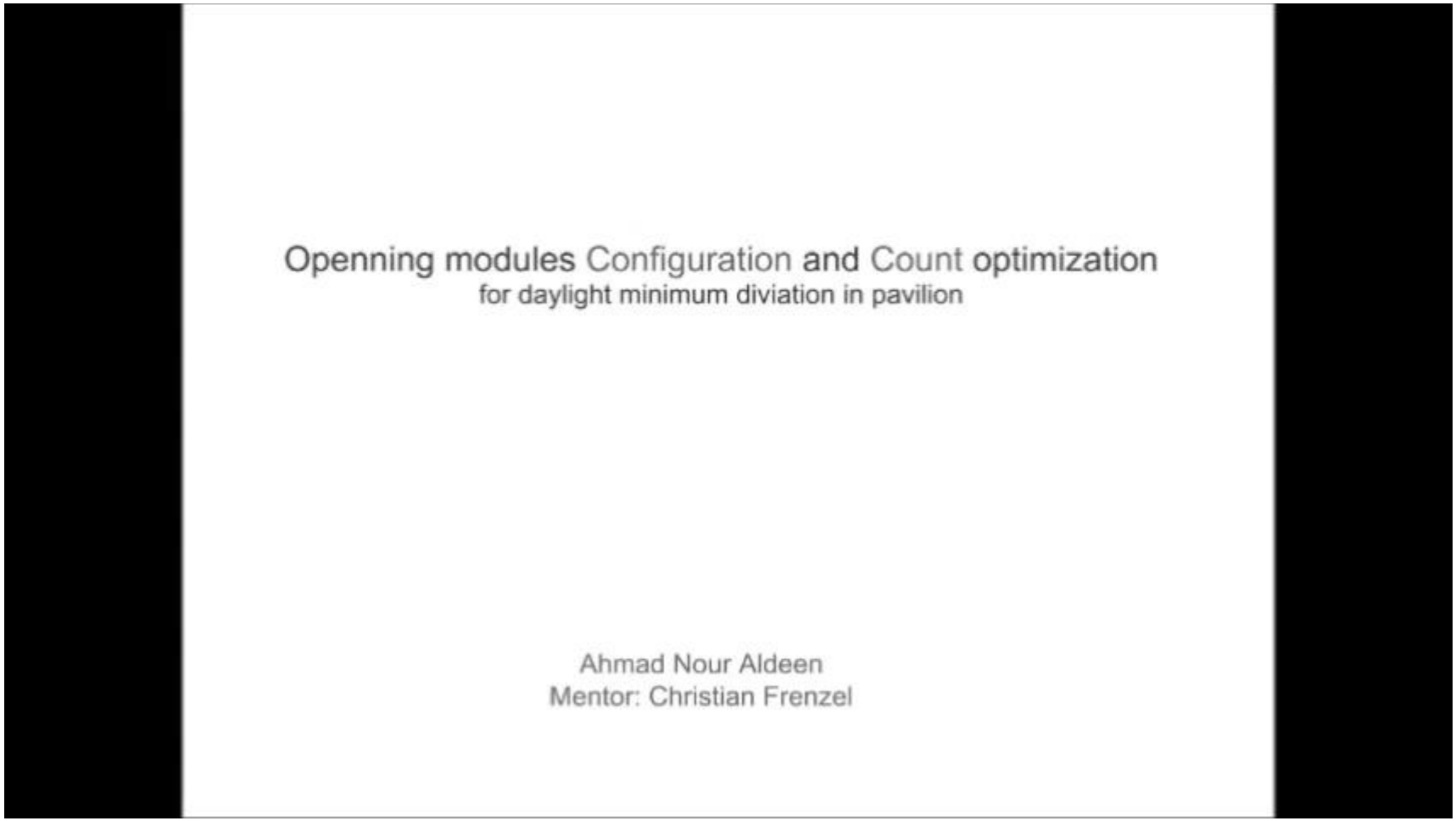
0.9 coefficient of solar absorptions (black ground)
0.1 wind factor (almost no wind)
with membrane (in shade)
adiabatic cooling on



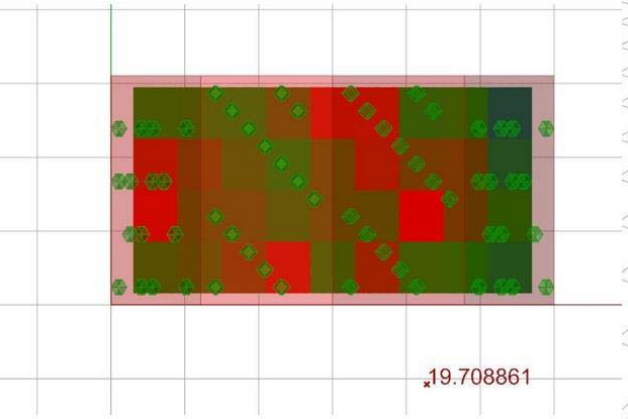


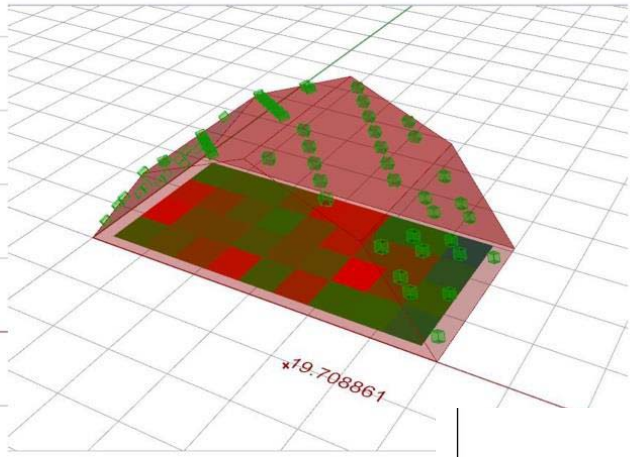

Base Case 1
Annual
Case 4
For the Cold Section
Case 6
For the Hot Section
+
Heat Stress
No thermal Stress
Cold Stress
28
12
UTCI Equivalent Temperature (°C)
extreme heat stress
very strong heat stress
strong heat stress
moderate heat stress
no thermal stress
slight cold stress
moderate cold stress
strong cold stress
very strong cold stress
extreme cold stress
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
-50<=UTCI<-40
-40<=UTCI<-27
-27<=UTCI<-13
-13<=UTCI<0
0<=UTCI<9
9<=UTCI<26
26<=UTCI<32
32<=UTCI<38
UTCI>=38

Design for the homogeneity of Daylight inside and the Radiation on the surface for the plants



60 openning

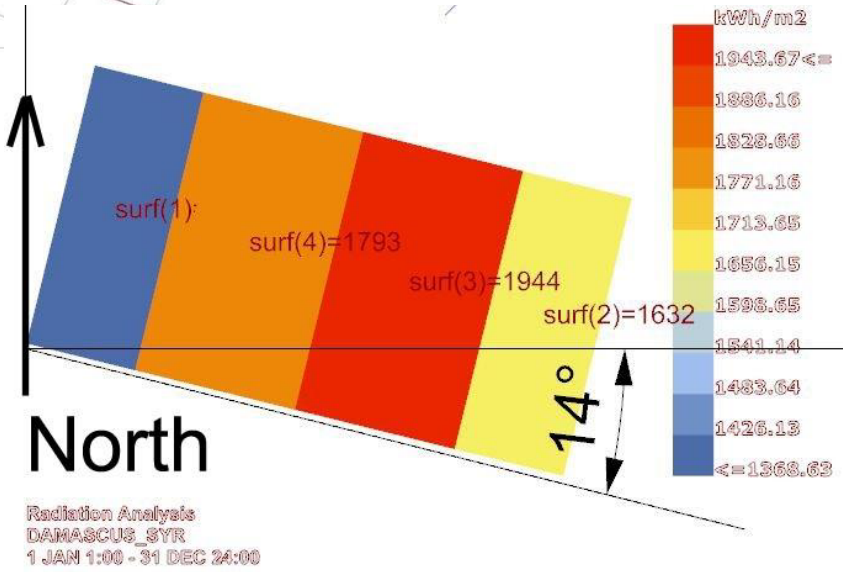




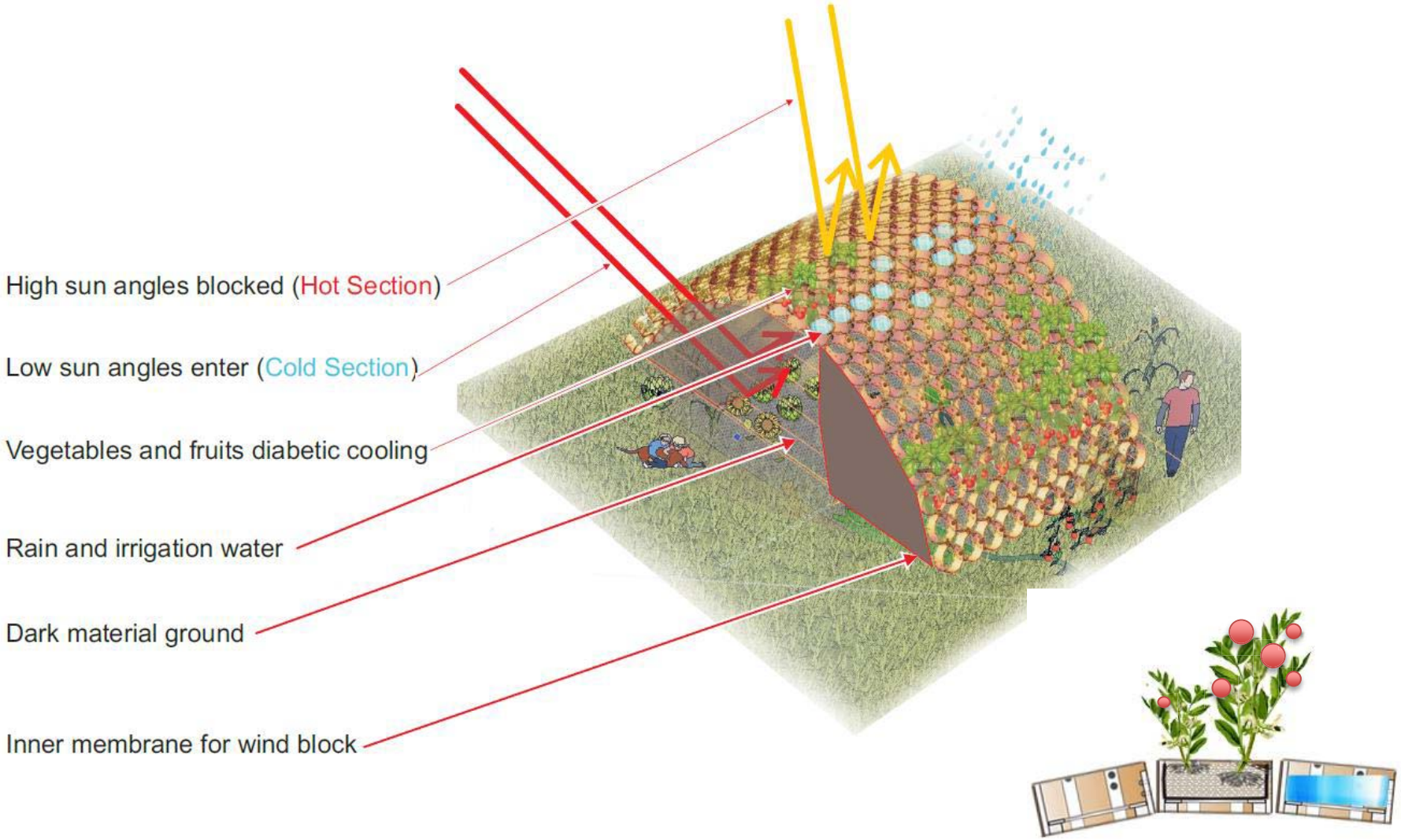
Final opening organization
Average Daylight = 1.74

Avrg. DL = 1.74

Min Deviation = 6.1



Final orientation for pavilion
for radiation on surfaces


High sun angles blocked (Hot Section)
Low sun angles enter (Cold Section)
Vegetables and fruits diabetic cooling
Rain and irrigation water
Dark material ground
Inner membrane for wind block

-Keep existing roof

-create an earth shelter inside

-Harvest rain water

-distribute to planted vegetables and fruits

-harvest and replace pods

-live and enjoy comfort inside !

NEXT!

Pipes arrive !

Cut and take
down to Keller!

Mark and cut!

Mark and drill!

Assemble in modules!

To fit TS car

Ready to build !

Next stop Killesberg!!

Waiting for you 26 Sept ☺!!