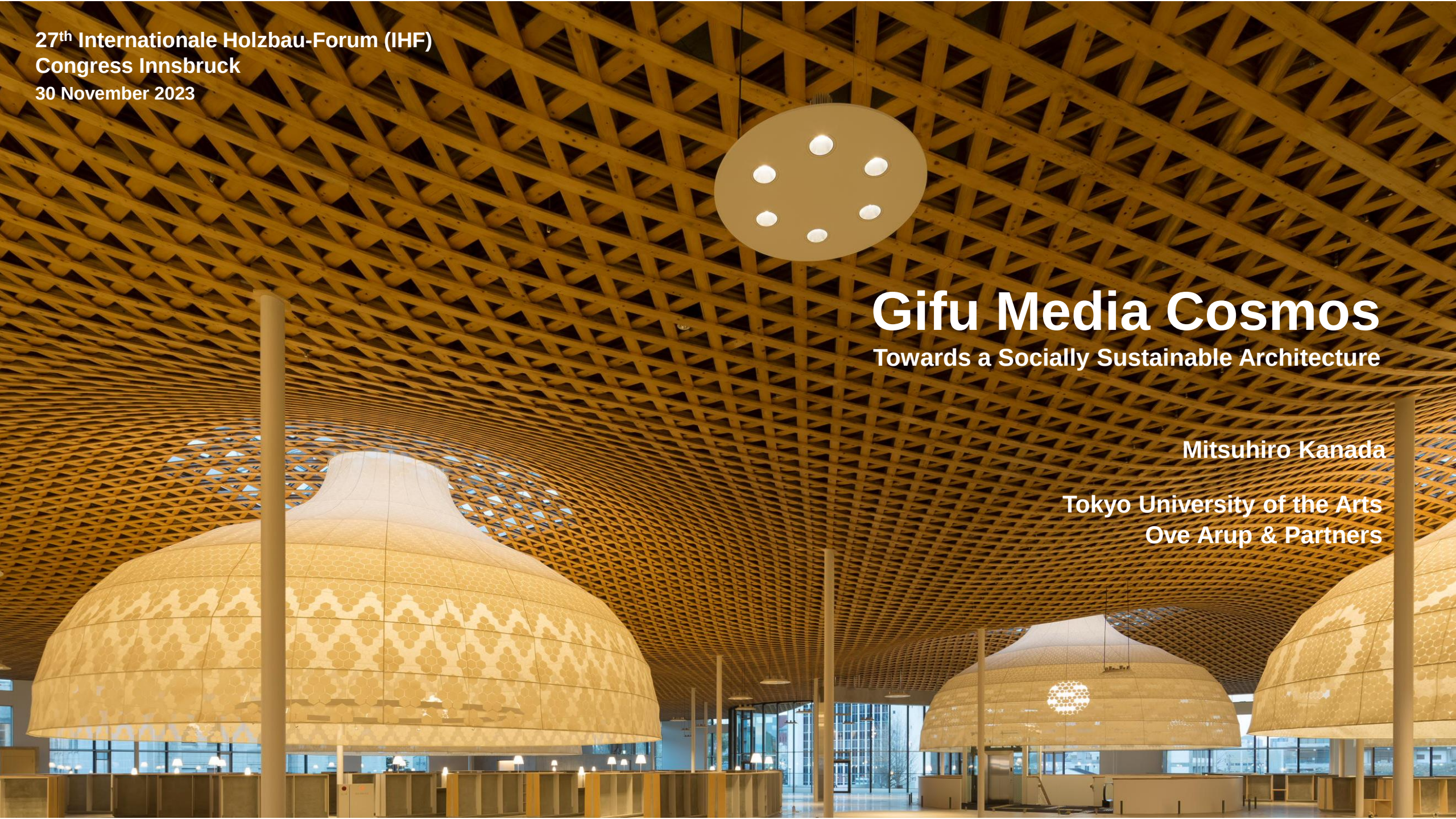
27th Internationale Holzbau-Forum (IHF)
Congress Innsbruck
30 November 2023



Gifu Media Cosmos

Towards a Socially Sustainable Architecture

Mitsuhiro Kanada

Tokyo University of the Arts
Ove Arup & Partners

SOCIAL & CULTURAL CONTEXT

- Not just what we designed
- Why and how we realized the project

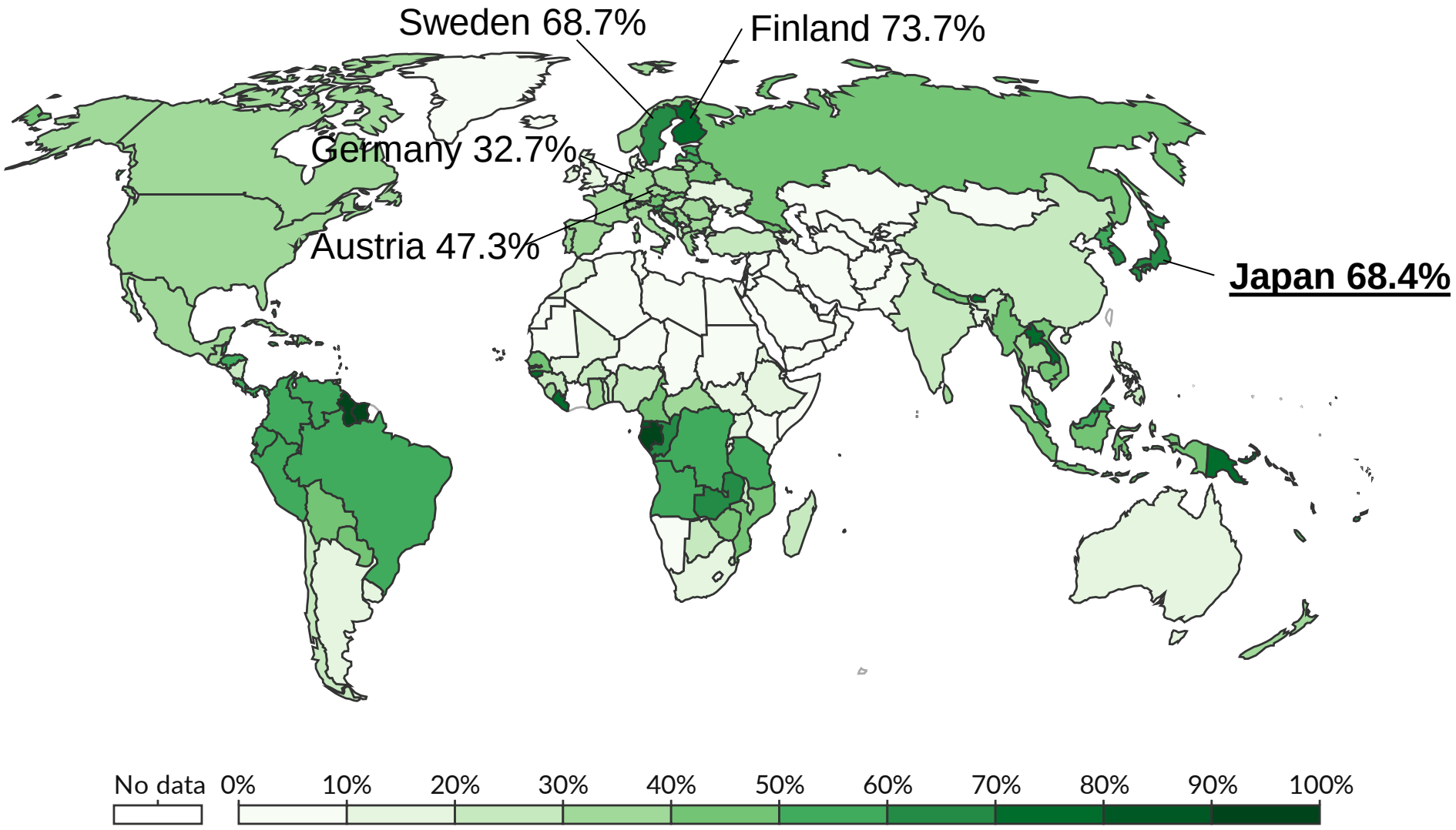
You might think Japan is very crowded, with very high population density…

Morning commute…

Share of land covered by forest, 2020

Our World in Data

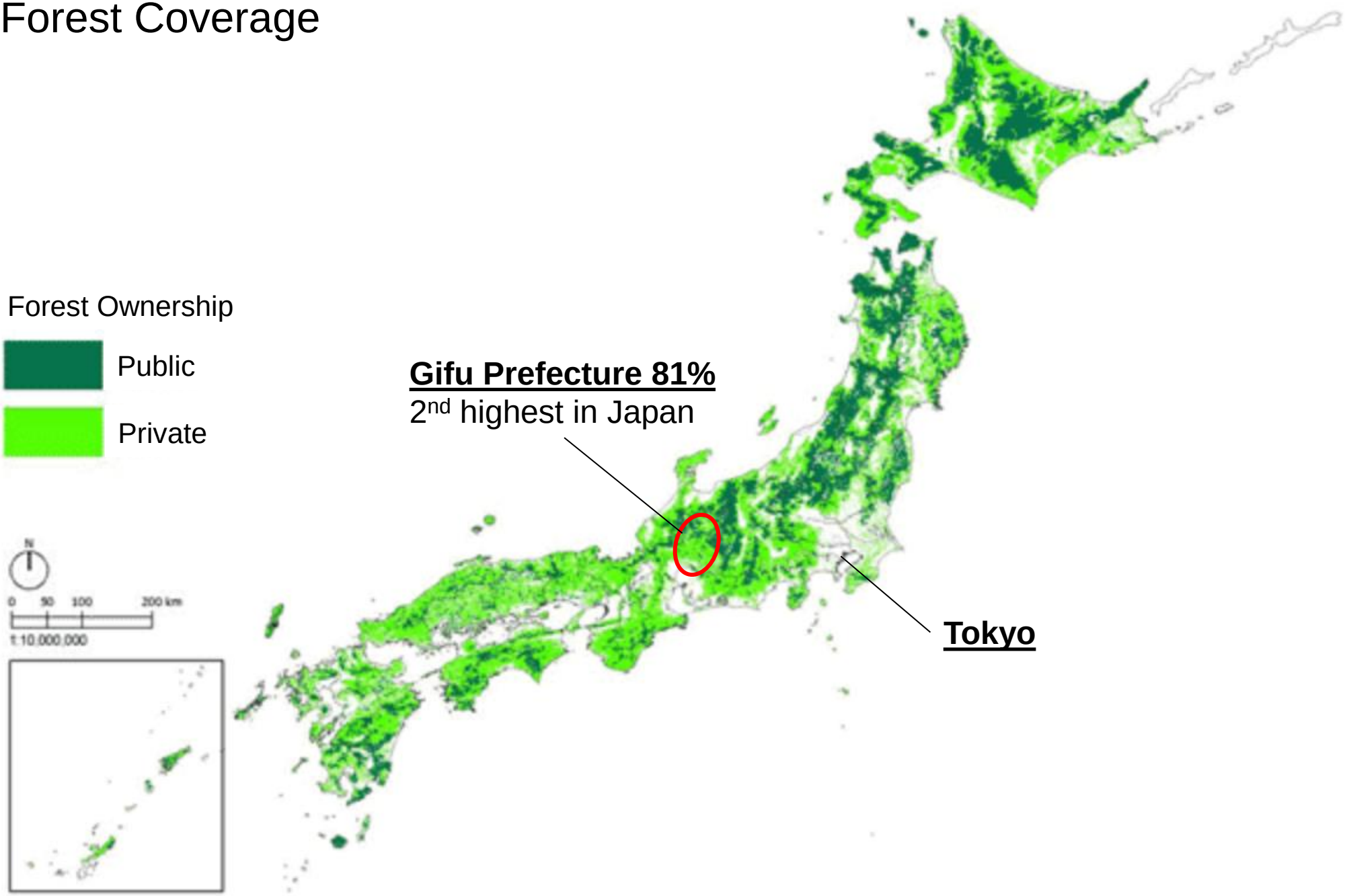
Forest area is land with natural or planted stands of trees at least five meters in height, whether productive or not, and excludes tree stands in agricultural production systems.



Data source: Food and Agriculture Organization of the United Nations and historical sources

OurWorldInData.org/forests-and-deforestation | CC BY

Forest Coverage



SOCIAL & CULTURAL CONTEXT

- Mountainous and not suitable for modern large-scale forestry
- Carpenters tend to be self employed and local contractors are often small scale
- Very high forest coverage near site
- 85% of single detached houses (60% of all housing type) are built in timber
- People like timber culturally, it needs to be visible, tactile, and smell like timber

VISIBLE USE OF MASS TIMBER

Obayashi Corporation, Training Center
in Yokohama, built in 2022

Sumitomo Forestry W350, planned for 2041
Height: 350m

ACCUMULATIVE USE OF SMALL DIMENTION TIMBER

Akita International University Library
Architect Prof Senda Engineer: Noriaki Yamada

Kogakuin University Archery Hall
Architect: Fukushima+Tominaga, Engineer: Shuji Tada

MAJOR CHALLENGES FOR TIMBER BUILDINGS

FIRE

Painting of city fire of Tokyo caused by Kanto Earthquake 1923

MAINTENANCE

If not maintained periodically, timber structures deteriorate fast.

Japanese for “Make” and “Maintain” has shared etymology

Make (or build) = “ Tsuku-ru”

Maintain = “Tsuku-rou”

To maintain means to make repeatedly and continuously

Built environment requires continuous human involvement

Like traditional Japanese timber structure.

TIMBER STRUCTURE DESIGN JOURNEY

Gifu City Library, Media Cosmos
With Toyo Ito Architects

How do you measure a success of structural engineering?
Connection details give a sense of scale and rhythm of the space.

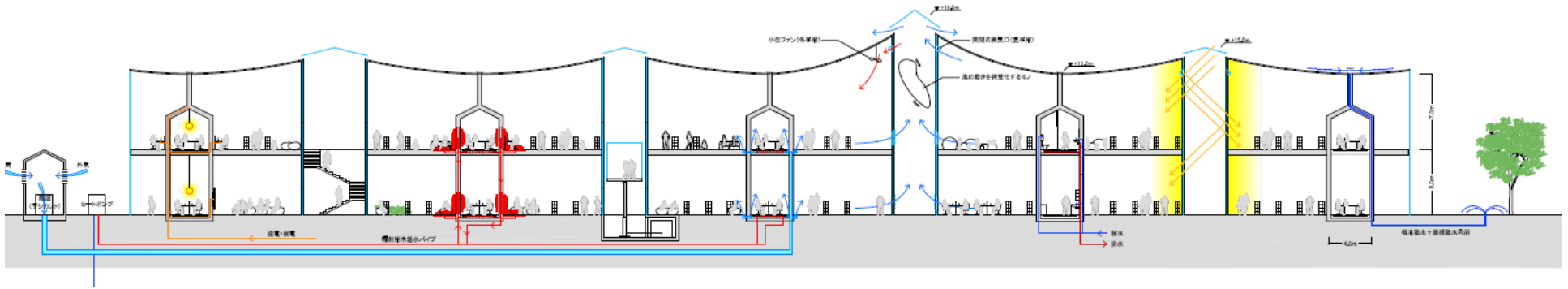
COMPETITION & CONCEPT MAKING

Collaboration to develop a shared vision
How the timber structural concept was developed

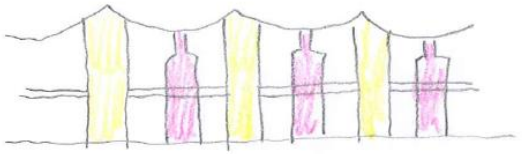
Structural engineer’s responsibility in materialization
of our built environment

2010.11.26 （When competition started）

Architectural concept is “Large house” and “Small Houses”



1次提案書にも書きました「大きな家」と「小さな家」というConsept を基に……



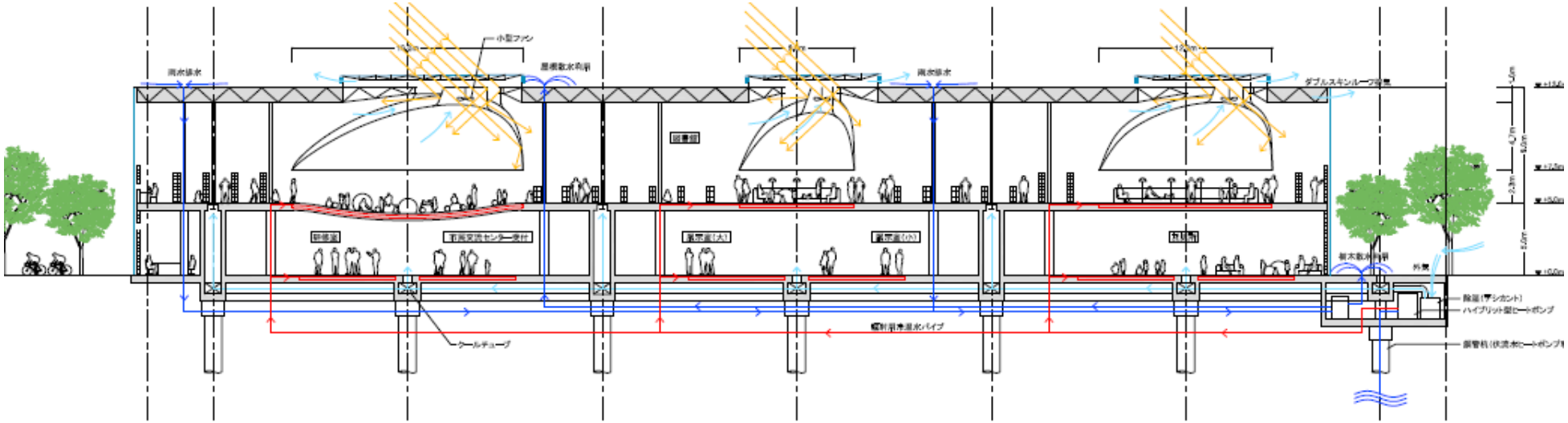
2種類の小さな家で大きな波のような屋根を支える

2階建ての建物を考えています。

2種類の小さな家は、tubeのように地面から屋根までをつなぎ、

構造や環境(etc)の様な要素を運ぶ役割を持ちます。

2010.12.06 (10 days later)



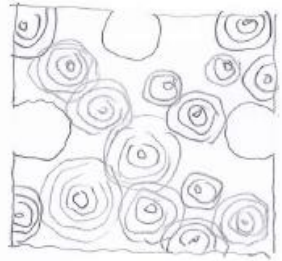
It is NOT about structure this time (by Toyo Ito)

Fellow environmental engineer suggested that ceiling height difference makes natural ventilation from the sky light more efficient
→ roof shape started to change

2010.12.09 (About 2 weeks from the beginning)

所内で、いろいろ話し合った結果...

以下のように考えていきたいと思っています。



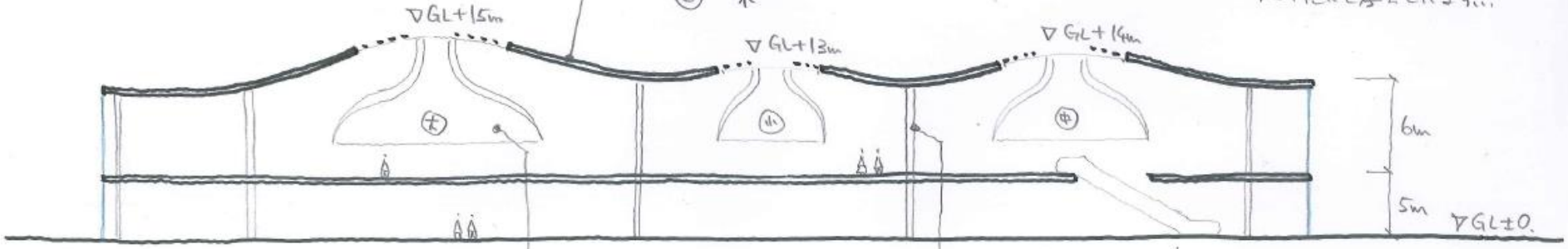
このようなイメージの屋根コンタライン。

街並や、上からの視線に配慮。

トラスではなくて、

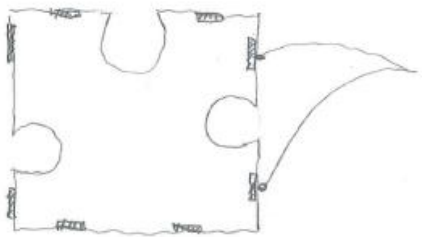
Ⓐ コンクリート
Ⓑ Steel サンドイッチパネル
Ⓒ 木

のいずれかを使って、板状の湾曲する屋根を
つくりたいと考えています。



「くらげ」は、光、風の事を考えて
屋根スラブの高い位置に!!

柱は雨水管も兼ねて、
屋根スラブの低い位置に!!

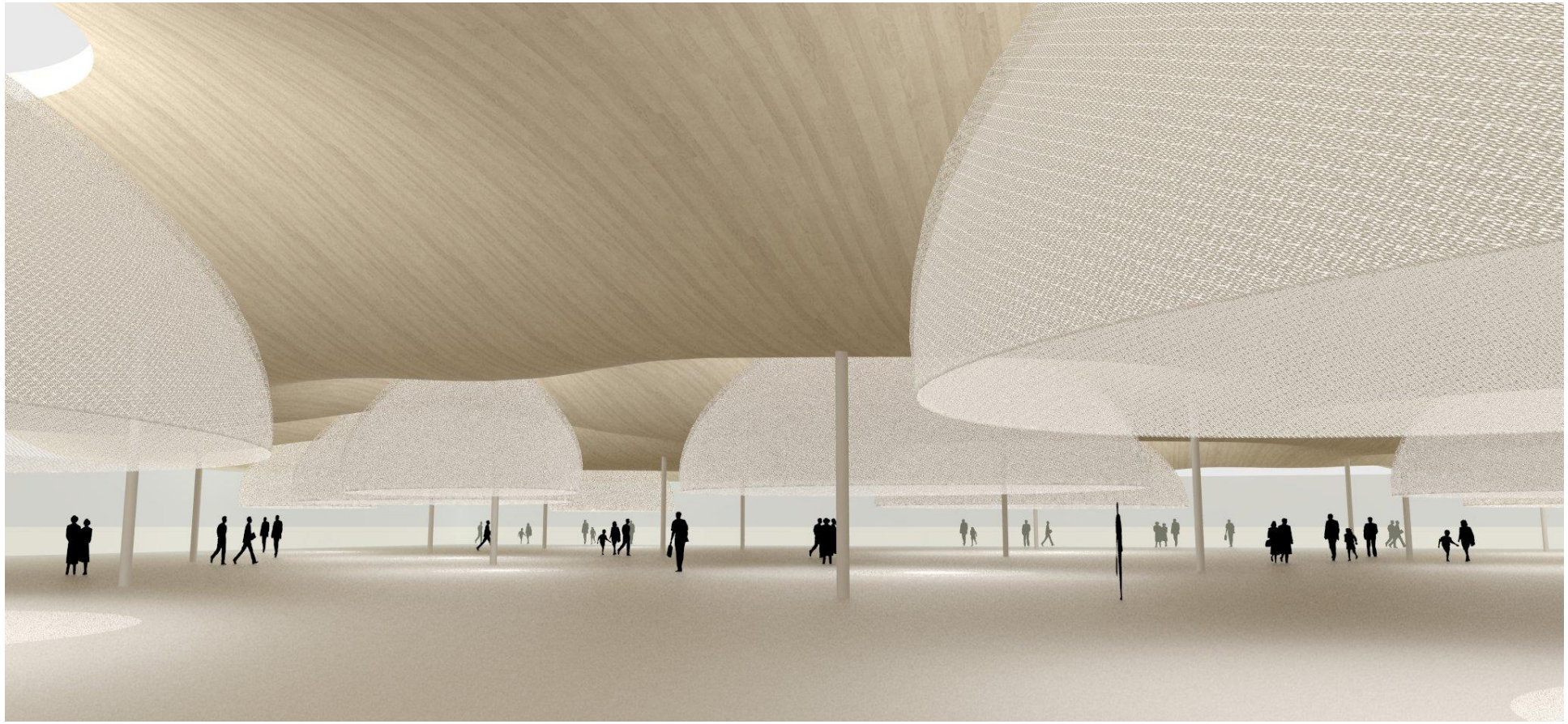


横力は、ハンチだけでも確保していけるのではないか。

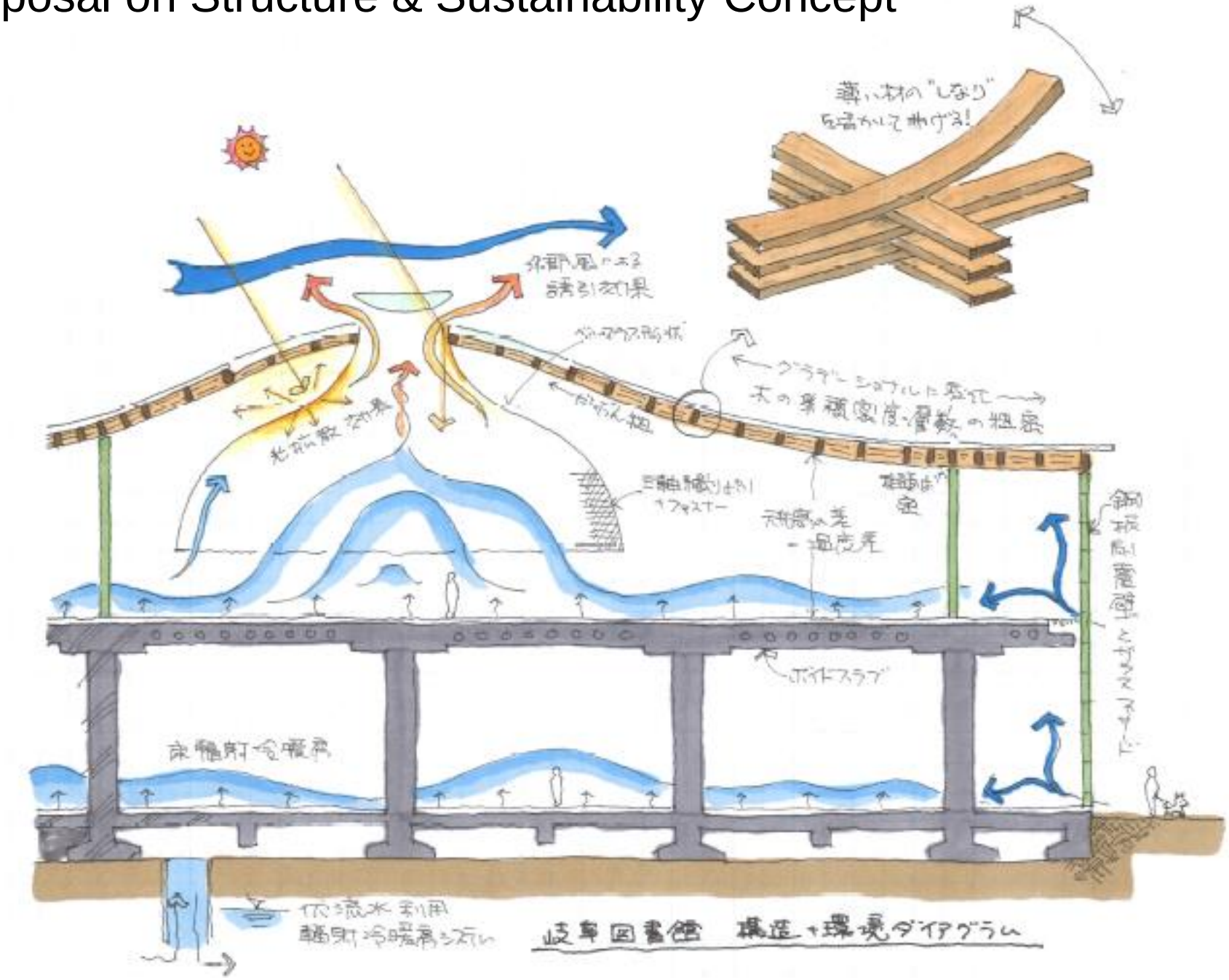
白差しをCutする役割も兼ねて、外周に散らばらせる
ように考えたいと思います。

2010/12/09
TIAA

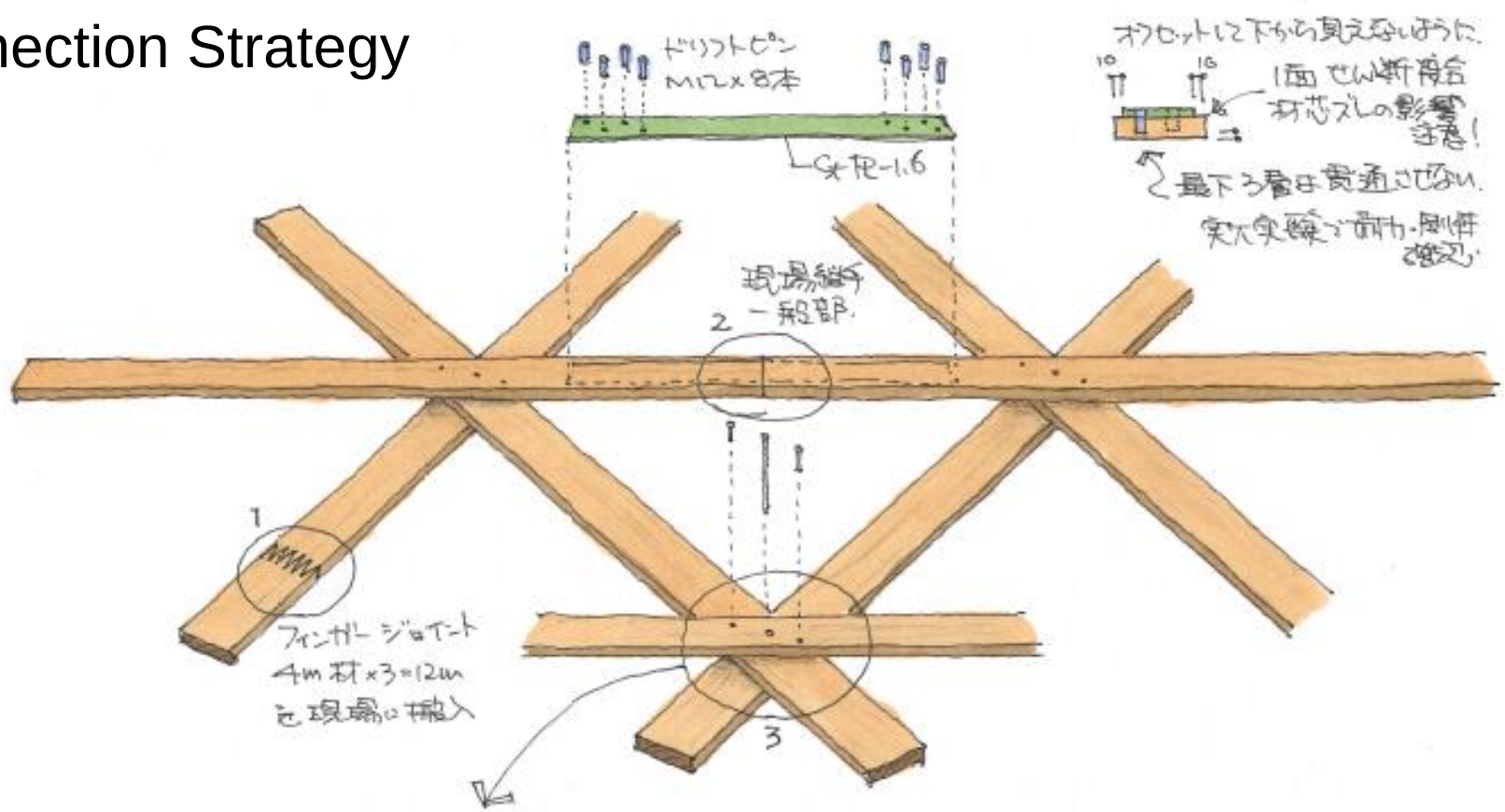
2010.12.16

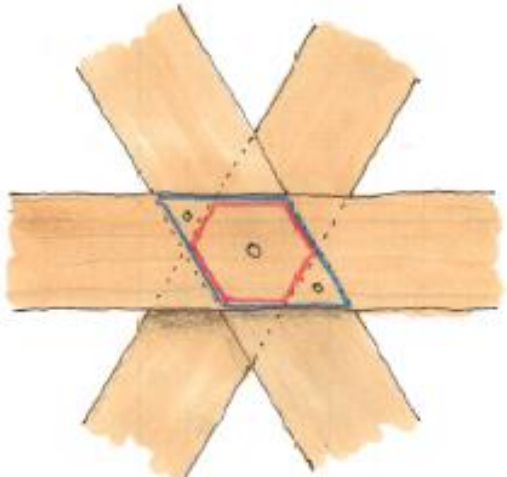


Proposal on Structure & Sustainability Concept



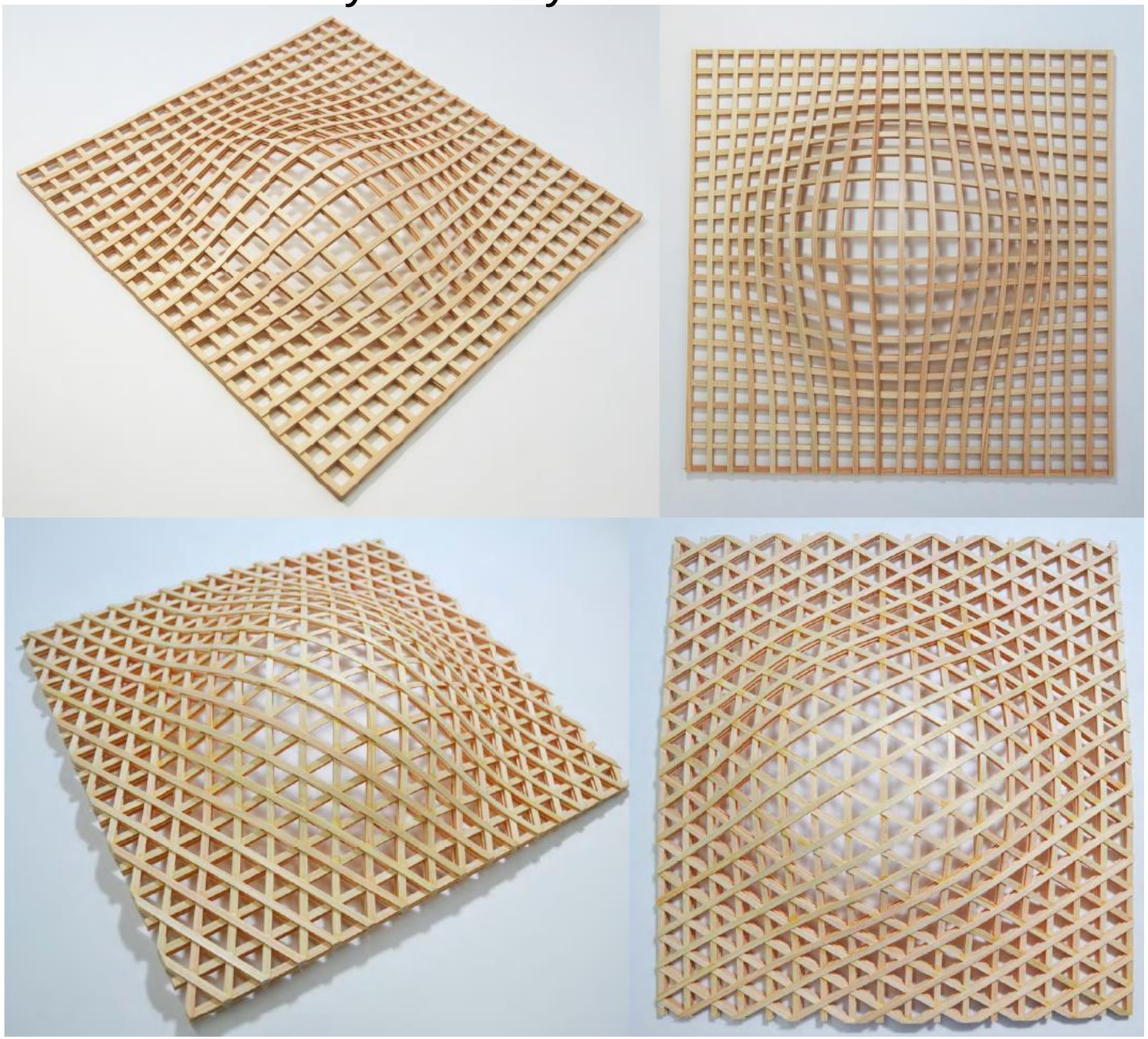
Connection Strategy

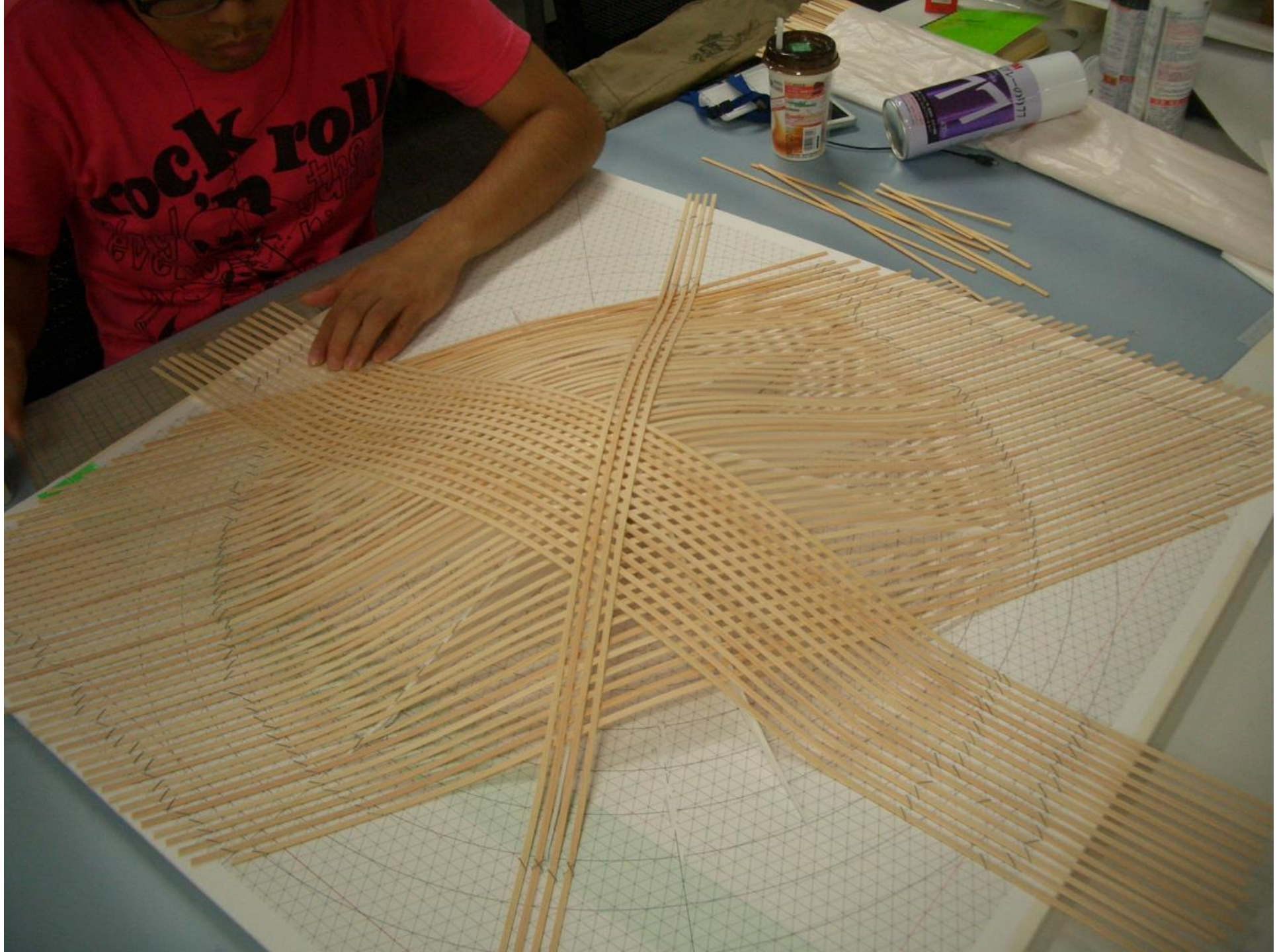




ビスやドリフトピンが下から一切見えないシームレスな架構体を目指す!!

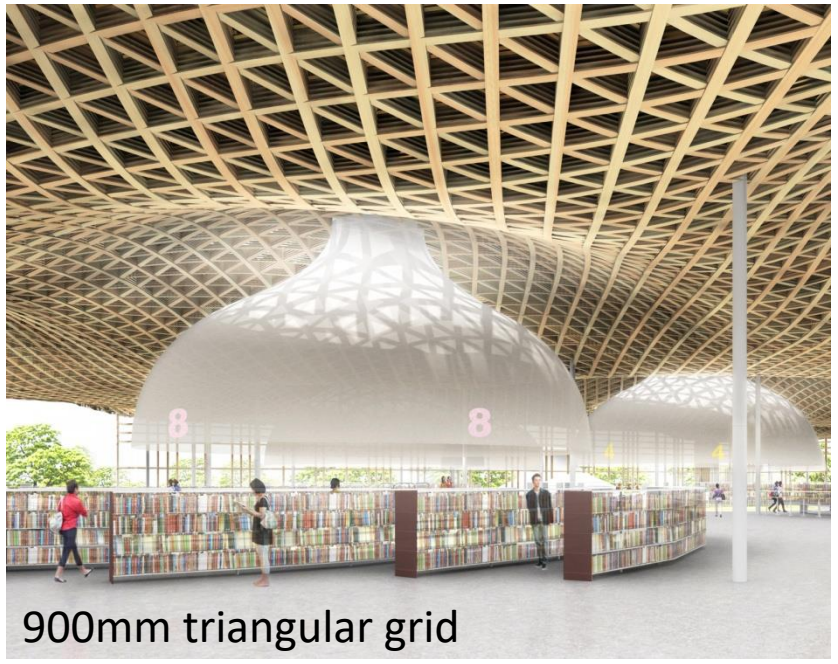
Structural Study with Physical Models




ock roll

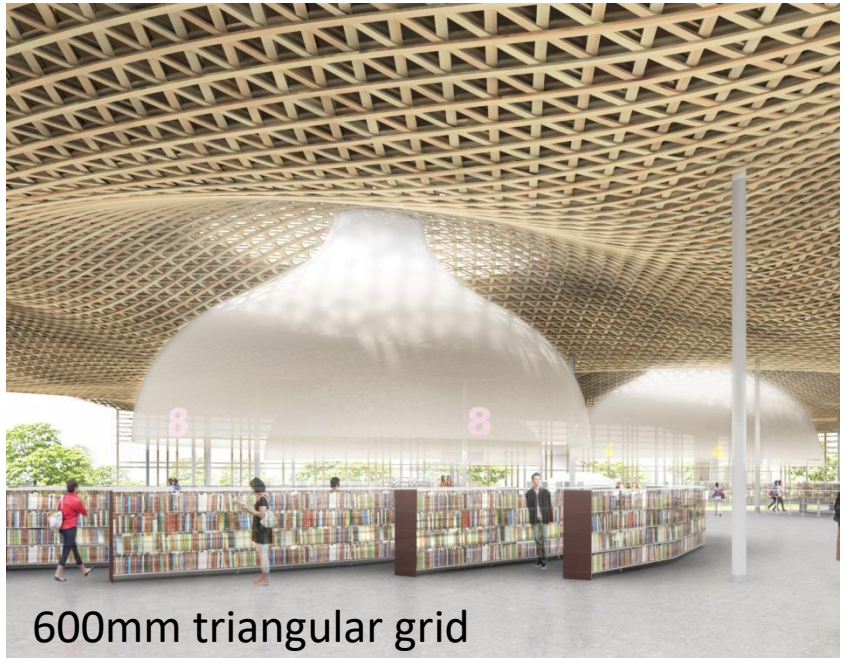

TOKYU HAN

Grid Study



900mm triangular grid

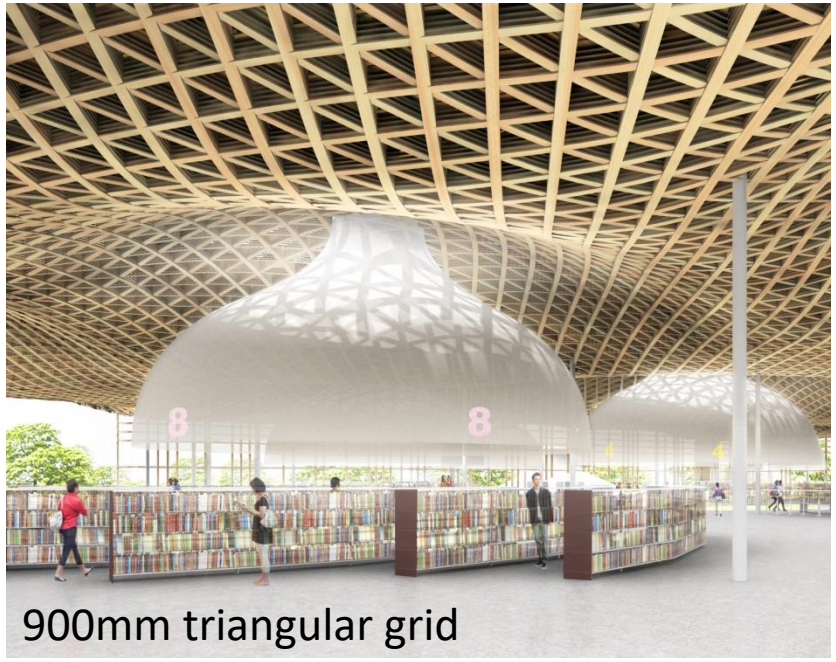
450mm triangular grid

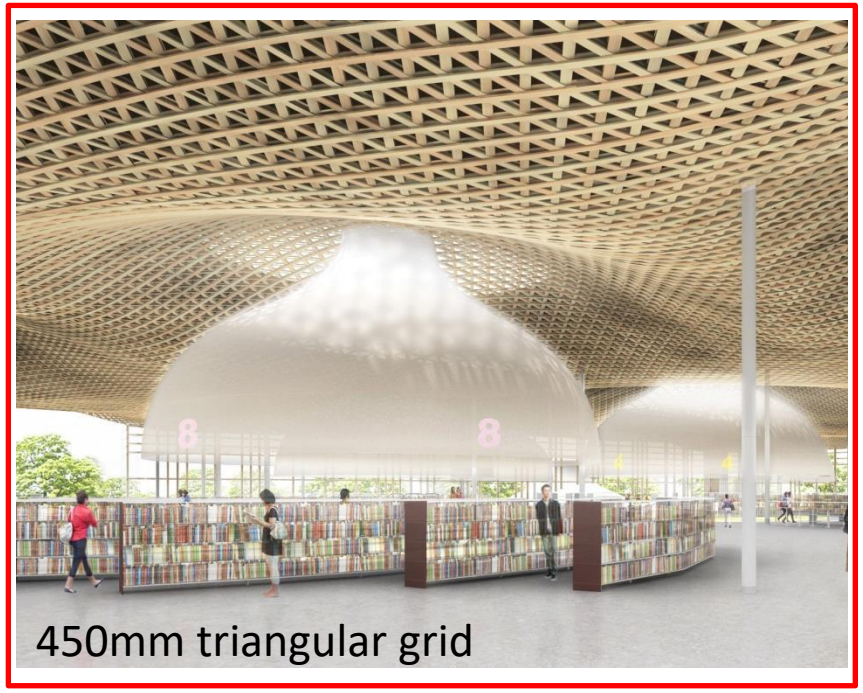


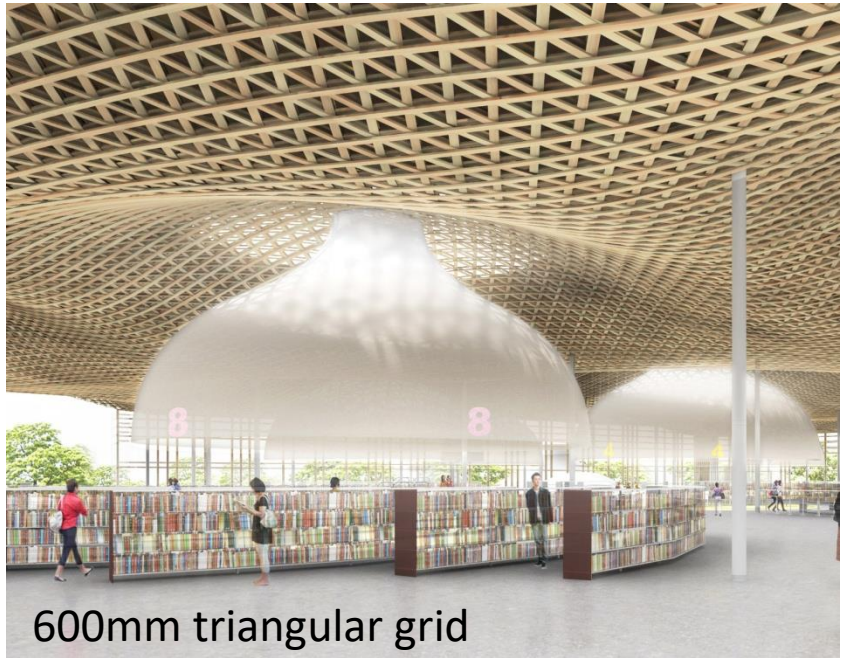
600mm triangular grid

450mm square grid

Grid Study

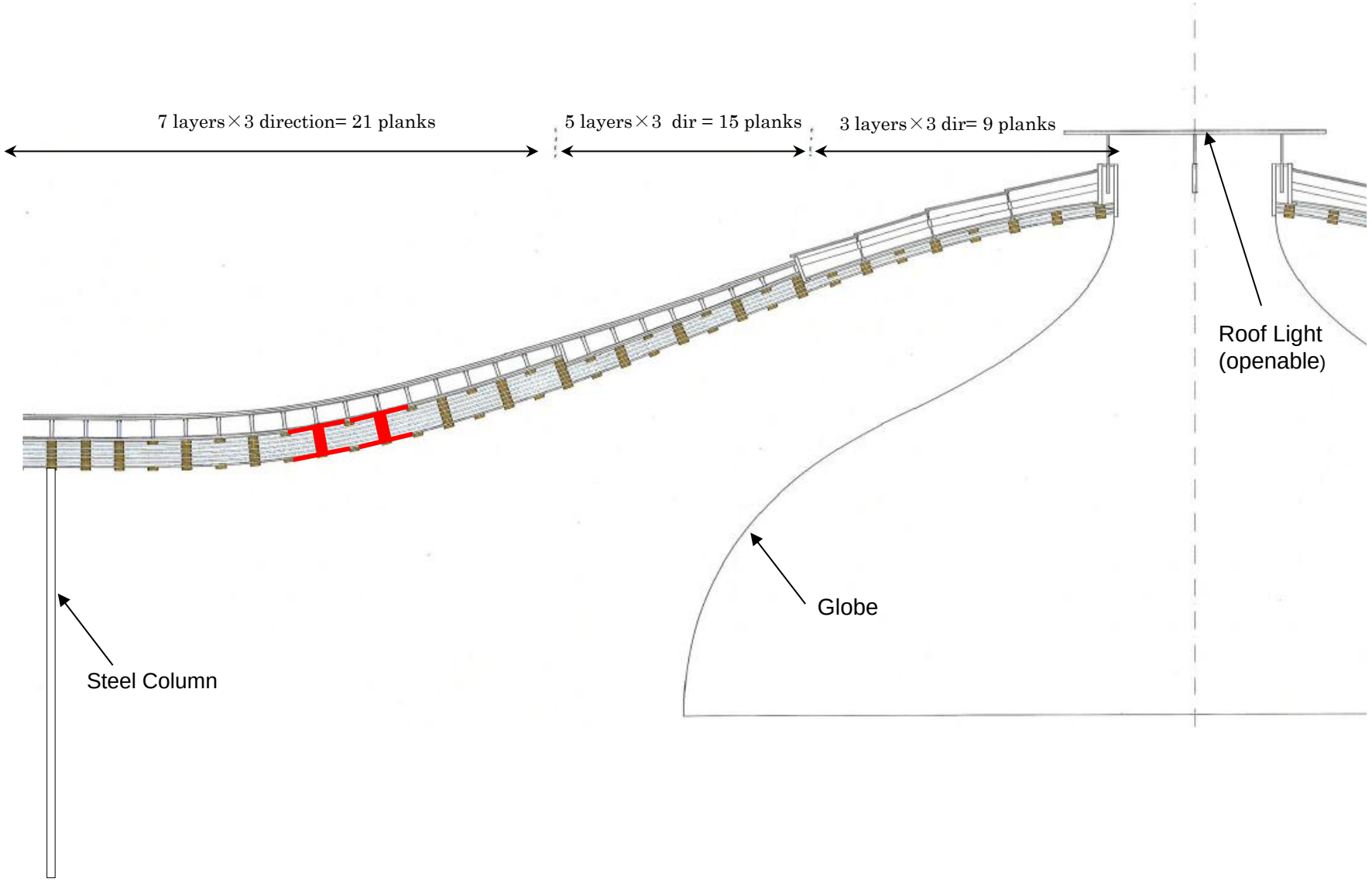

900mm triangular grid


450mm triangular grid


600mm triangular grid


450mm square grid

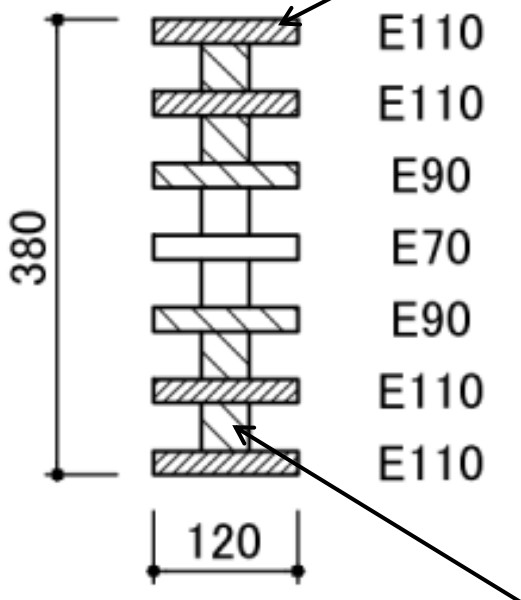
Timber Roof Section

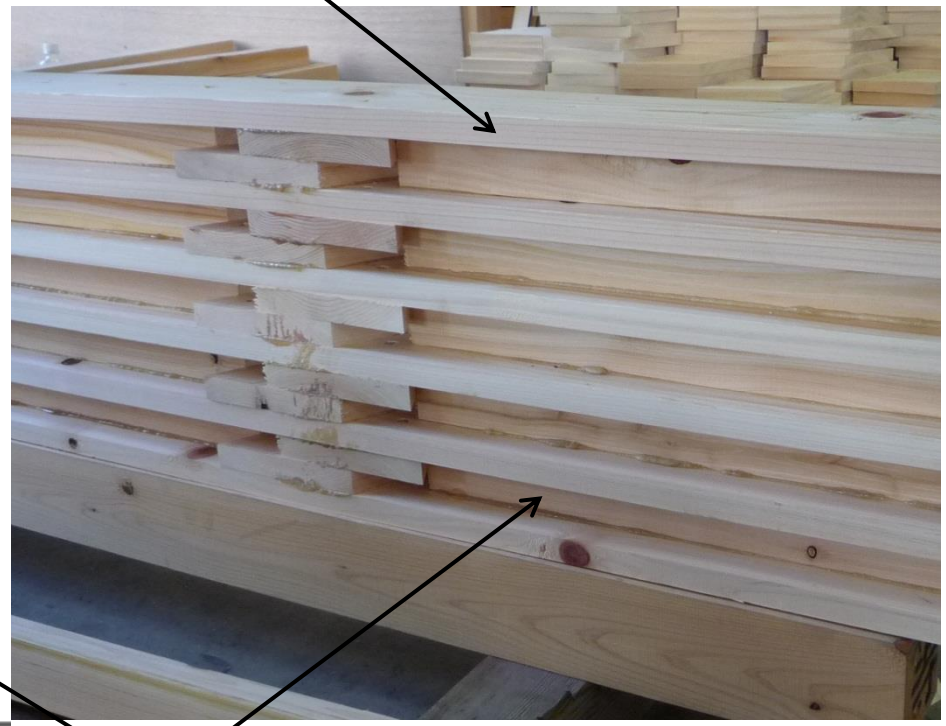


Number of layers vary depending on structural demands

Typical Member Buildup

120mm x 20mm (Japanese Cypress)

Section	
Laminar	B × D = 120 × 20 (7層)
Spacer	B × D = 40 × 40 (E90,E70)



Spacer

Mechanical Grading E70・E90・E110

Local Japanese Cypress used 800m^3
Laminar total length about 200 km


8
8
4
4
3
10
7

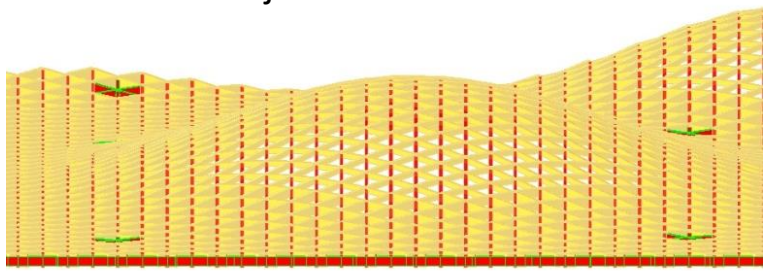
GEOMETRY & STRUCTURE

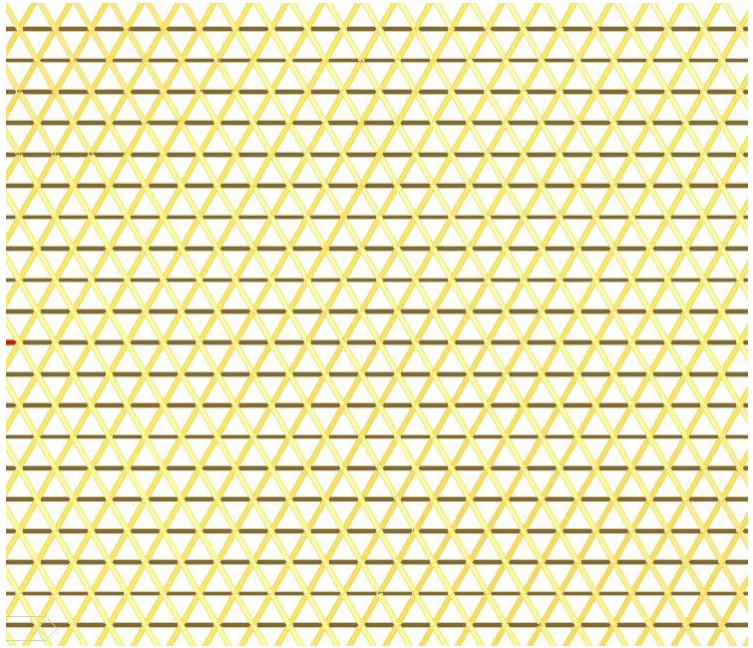
Geometrical rules established by structures

This is the key process to integrate the structure and architecture

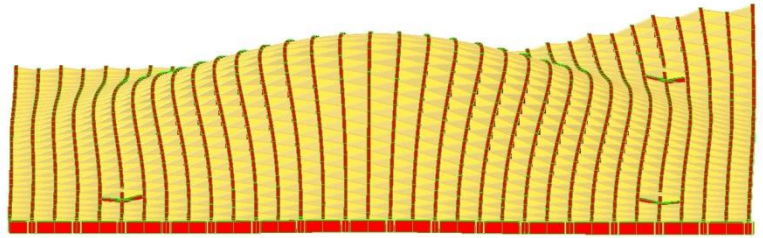
Initial stress check

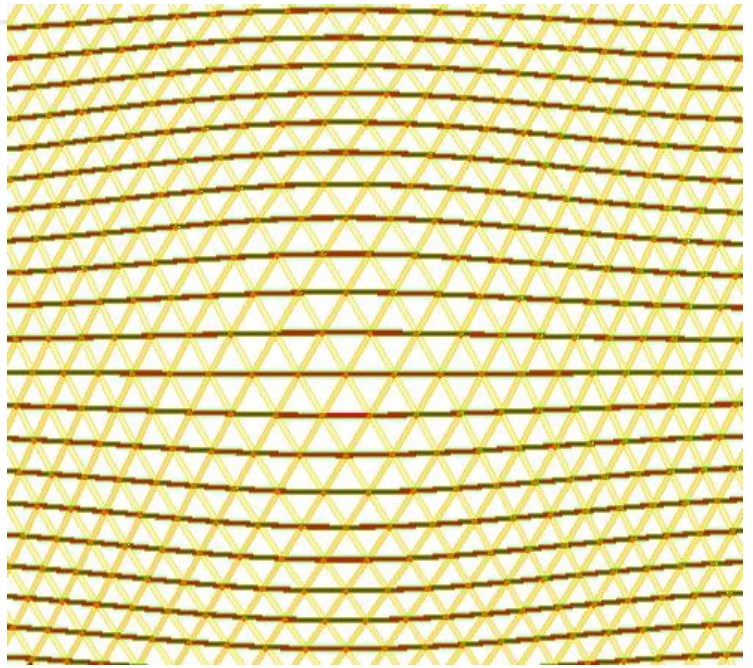
Projection Global z

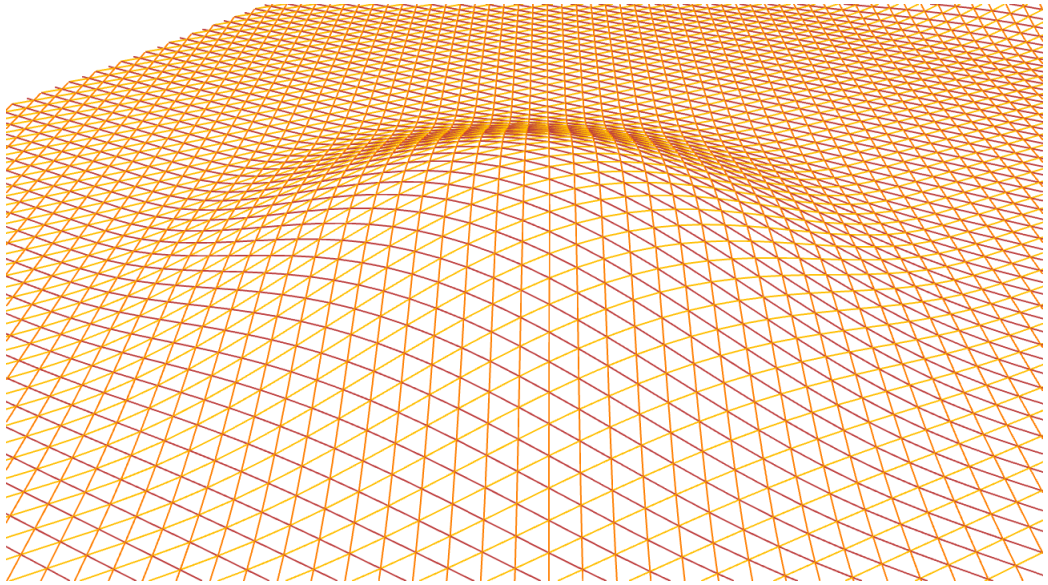


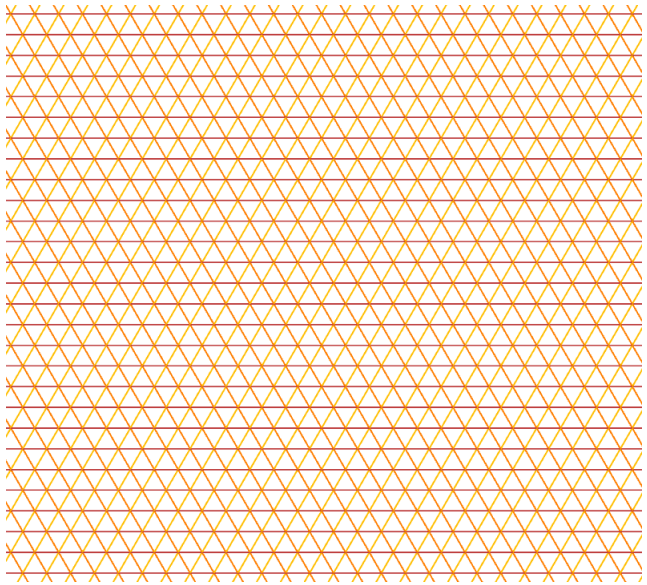


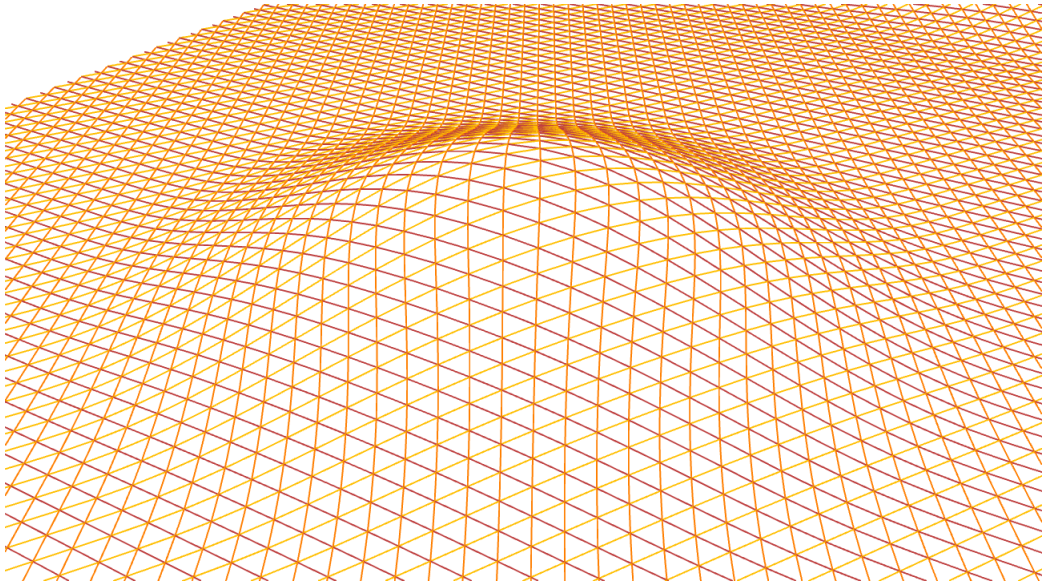
Projection Local z

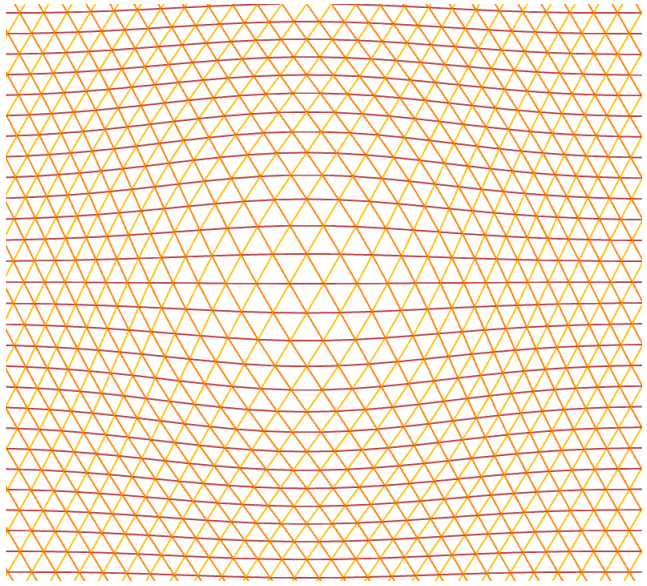




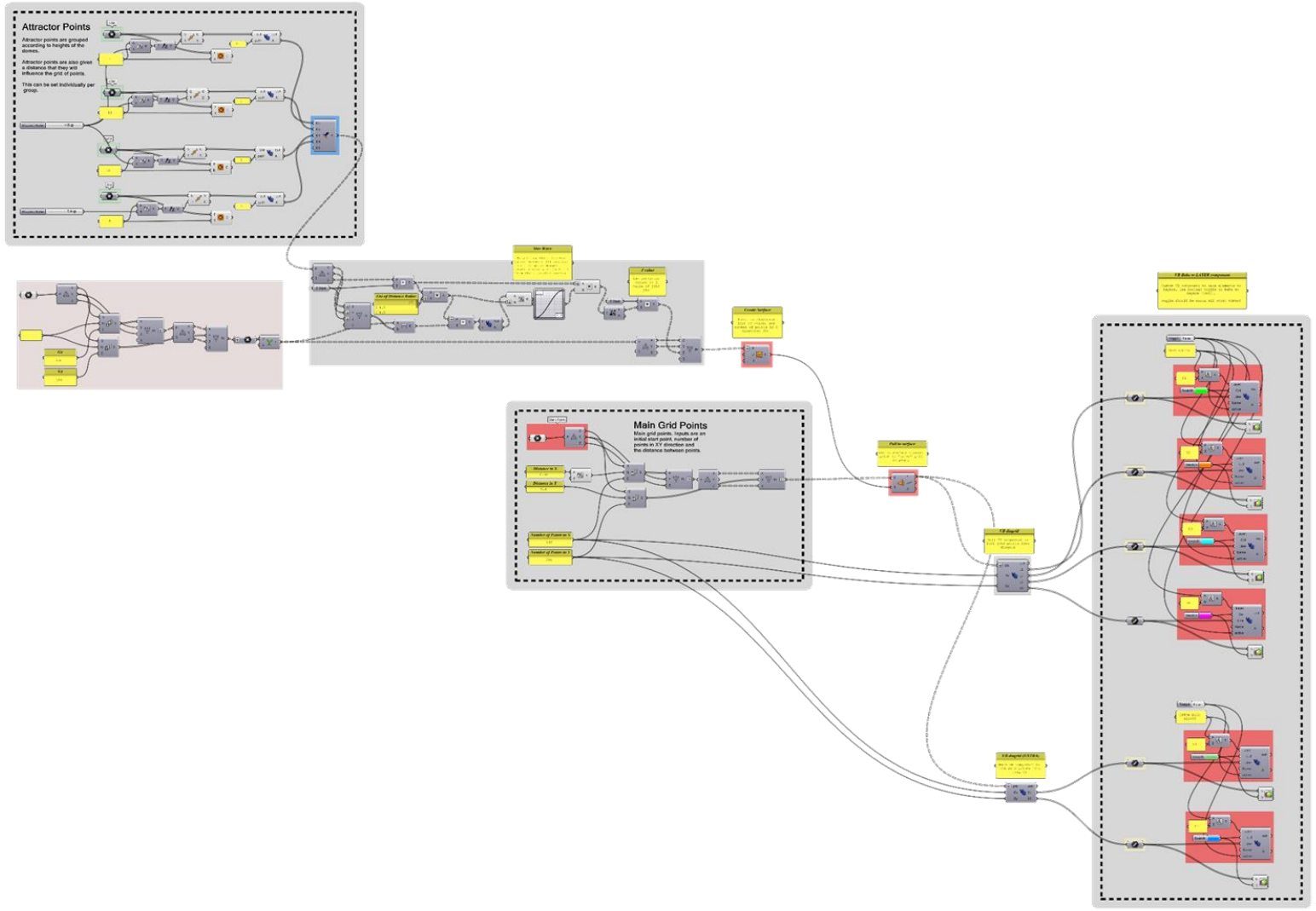


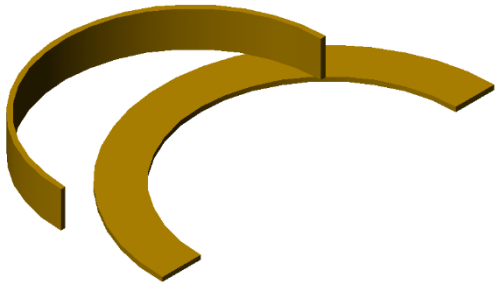


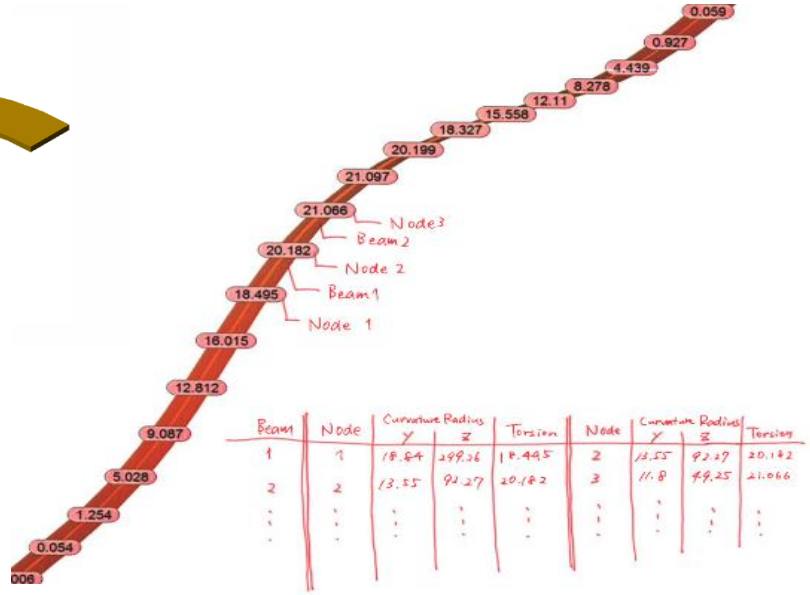




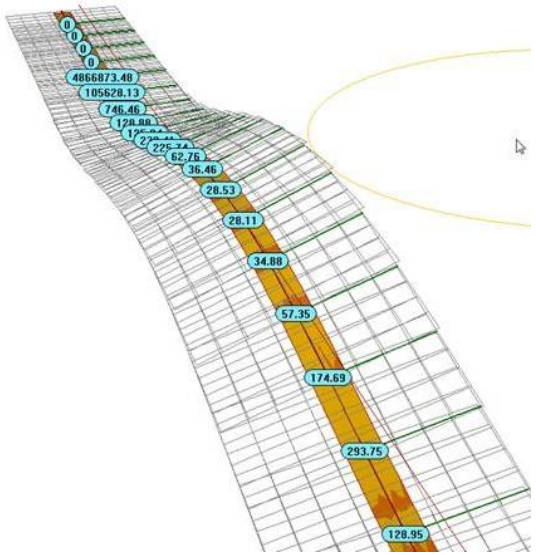
Geometry
Diagrid Definition



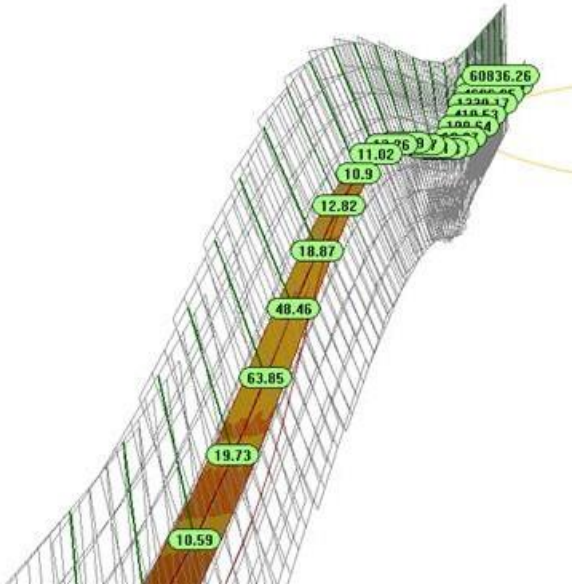




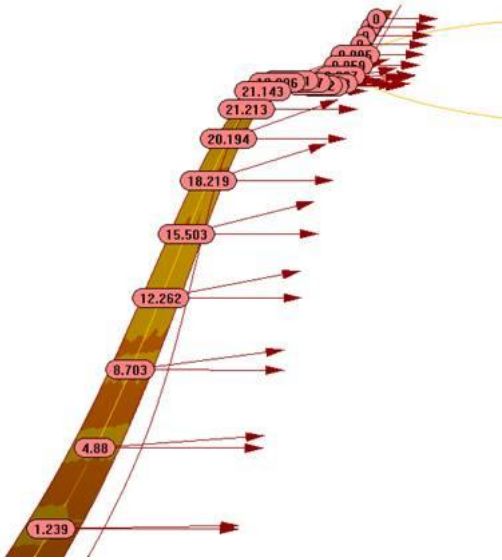
Gsa Node No	Cz	Cy	Angle
2876	86.04	17.74	4.119
3089	69.38	20.56	5.789
3302	59.44	29.52	7.53
3515	55.14	47.99	9.305
3728	54.46	129.89	11.072
3941	57.61	195.39	12.784
4154	67.63	56.45	14.389
4367	95.35	33.61	15.83
4580	227.63	24.31	17.054



Minor Axis

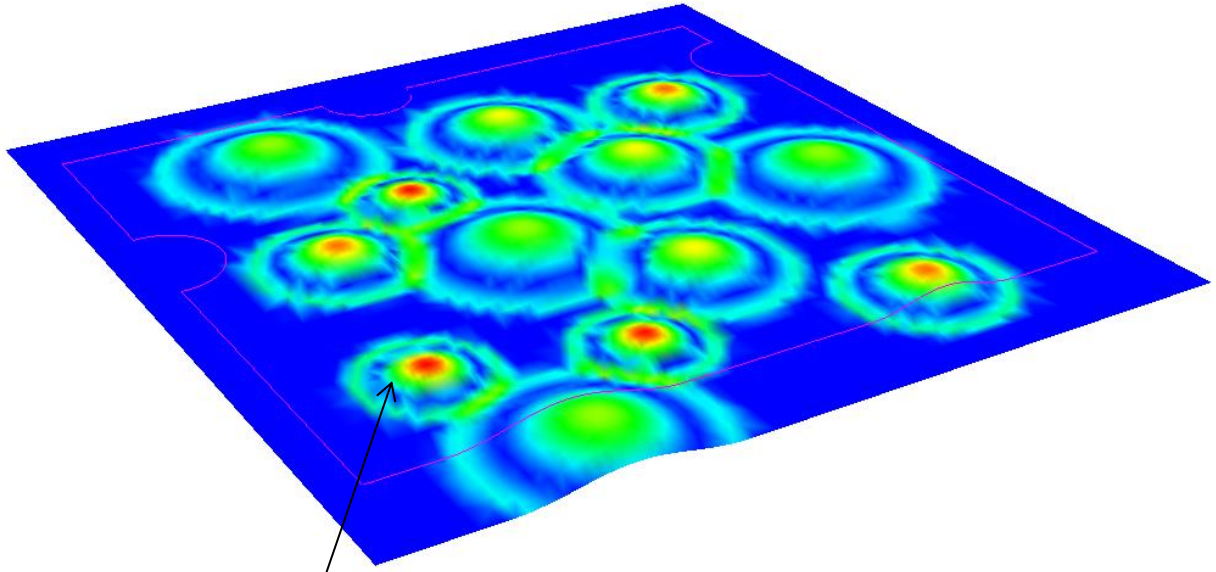


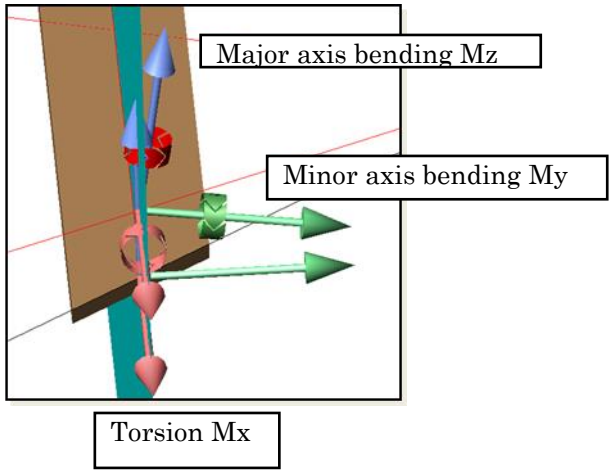
Major Axis



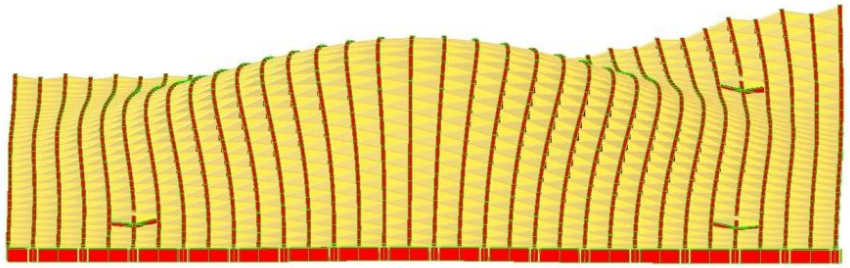
Torsion

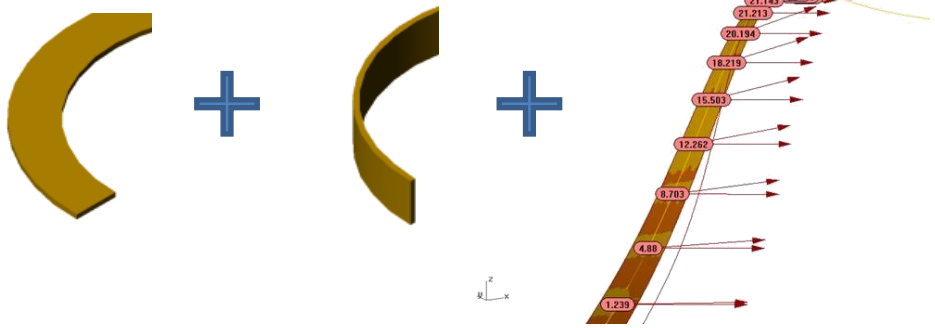
Initial stress due to bending in both minor and major axis



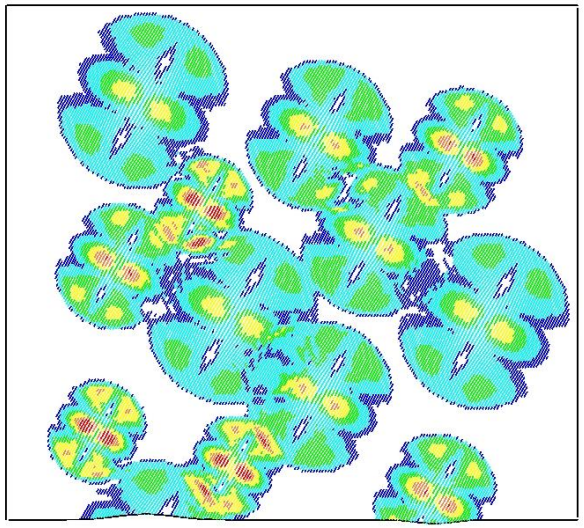


Major axis bending Mz | Minor axis bending My | Torsion Mx



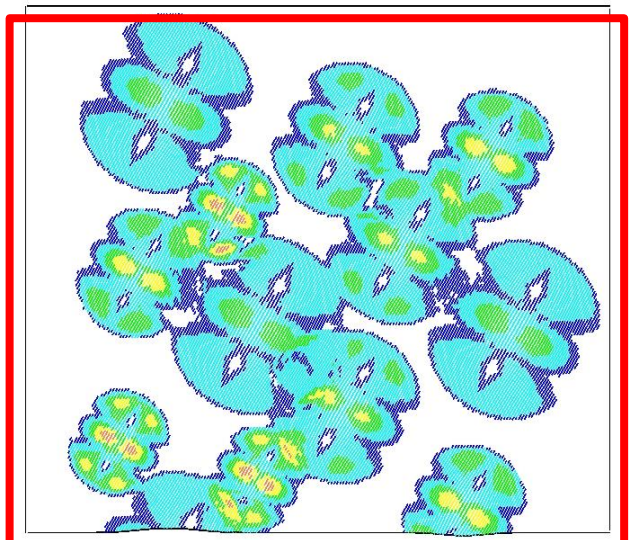


Initial Bending Stress



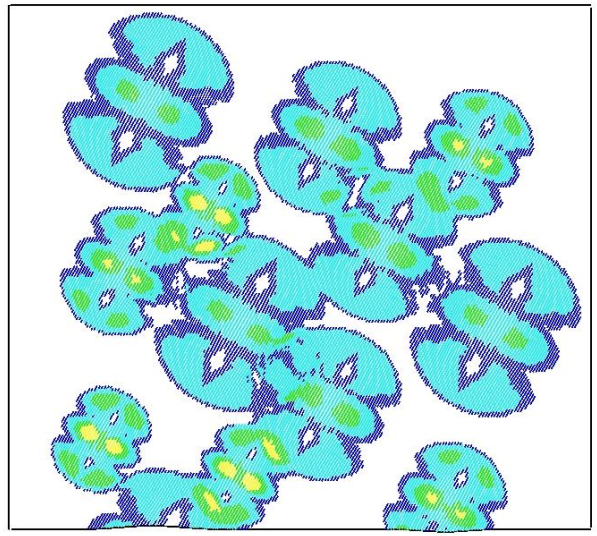
H=1/4 × D

	σb(N/mm2)	検定値	割合	全体の割合
	～1.28	0～	47.60%	47.60%
	～2.56	0.1～	12.58%	60.18%
	～5.11	0.2～	21.74%	81.92%
	～7.67	0.4～	12.32%	94.24%
	～10.23	0.6～	4.13%	98.37%
	～12.8	0.8～	1.28%	99.65%
	12.8～	1～	0.35%	100.00%



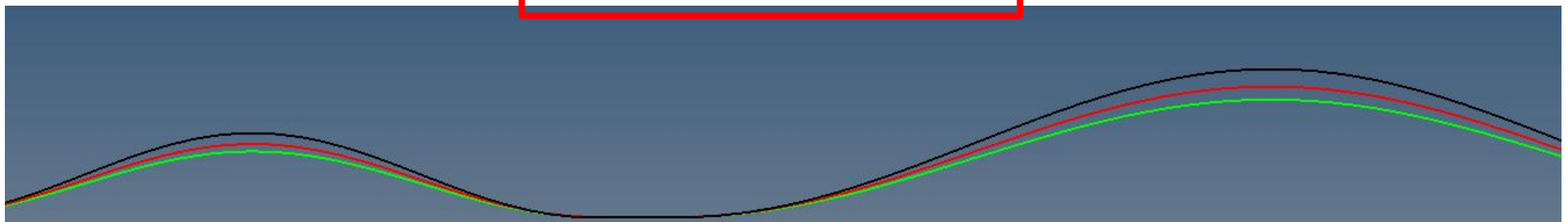
H=1/4.5 × D

	σb(N/mm2)	検定値	割合	全体の割合
	～1.28	0～	45.79%	45.79%
	～2.56	0.1～	11.11%	56.90%
	～5.11	0.2～	26.78%	83.69%
	～7.67	0.4～	12.83%	96.52%
	～10.23	0.6～	2.98%	99.50%
	～12.8	0.8～	0.46%	99.96%
	12.8～	1～	0.04%	100.00%



H=1/5.0 × D

	σb(N/mm2)	検定値	割合	全体の割合
	～1.28	0～	47.37%	47.37%
	～2.56	0.1～	13.71%	61.08%
	～5.11	0.2～	28.71%	89.78%
	～7.67	0.4～	8.81%	98.60%
	～10.23	0.6～	1.30%	99.90%
	～12.8	0.8～	0.10%	100.00%
	12.8～	1～	0.00%	100.00%



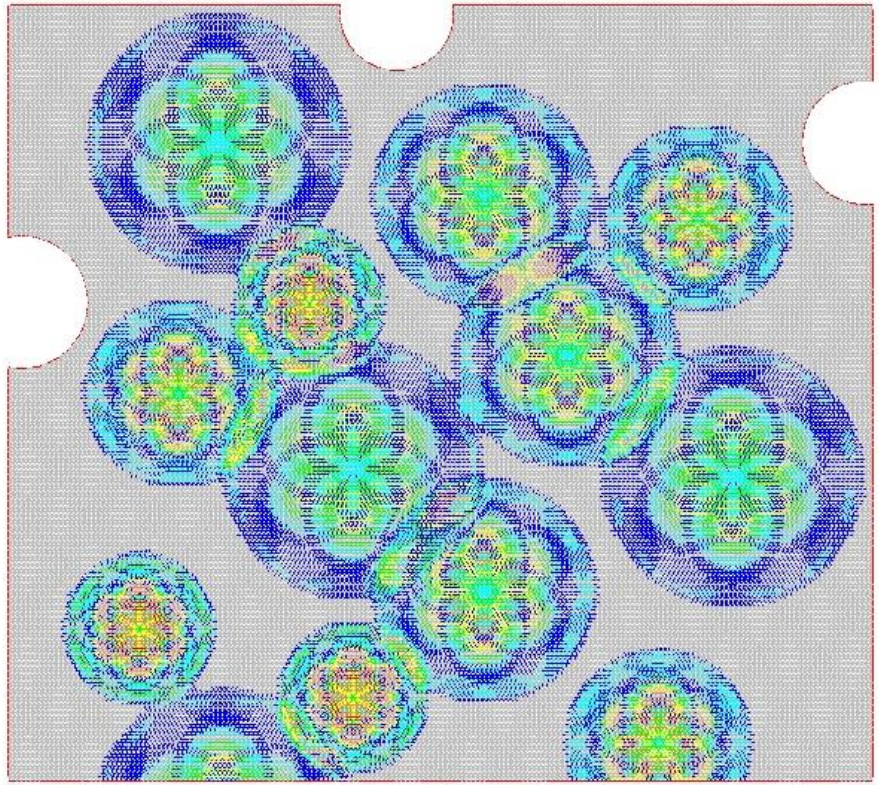
D(m)	1/4 H	1/4.5 H	1/5 H
14	3.50m	3.11m	2.80m
12	3.00m	2.67m	2.40m
10	2.50m	2.22m	2.00m
8	2.00m	1.78m	1.60m

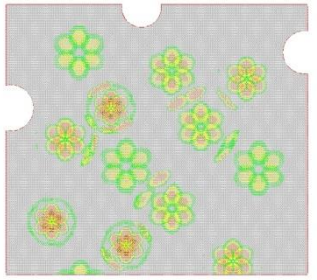
Original Surface 1 : 4

New Surface 1 1 : 4.5

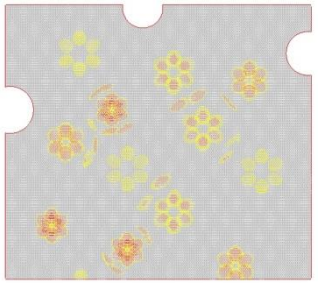
New Surface 2 1 : 5

Initial Bending Stress

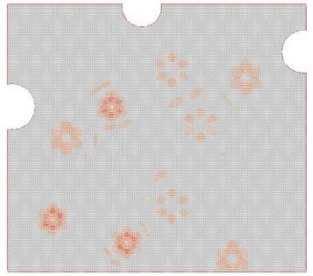




> 6N/mm²(検定値0.47)



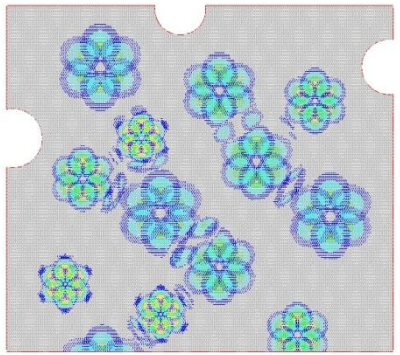
> 8N/mm²(検定値0.63)



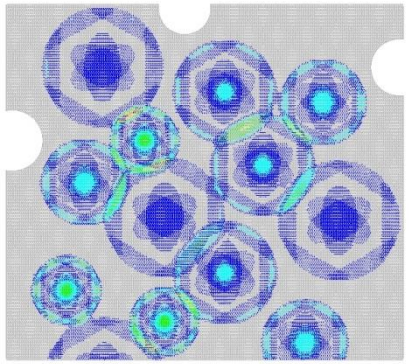
> 10N/mm²(検定値0.78)

B×D＝20×120　E=9000N/mm2 Creep2.0

	σb(N/mm2)	検定値	割合	全体の割合
	0～2	0～0.16	58.08%	58.08%
	2～4	0.16～0.31	18.09%	76.17%
	4～6	0.31～0.47	10.75%	86.93%
	6～8	0.47～0.63	6.09%	93.02%
	8～10	0.63～0.78	4.07%	97.09%
	10～15	0.78～1.18	2.72%	99.81%
	15～	1.18～1.34	0.19%	100.00%

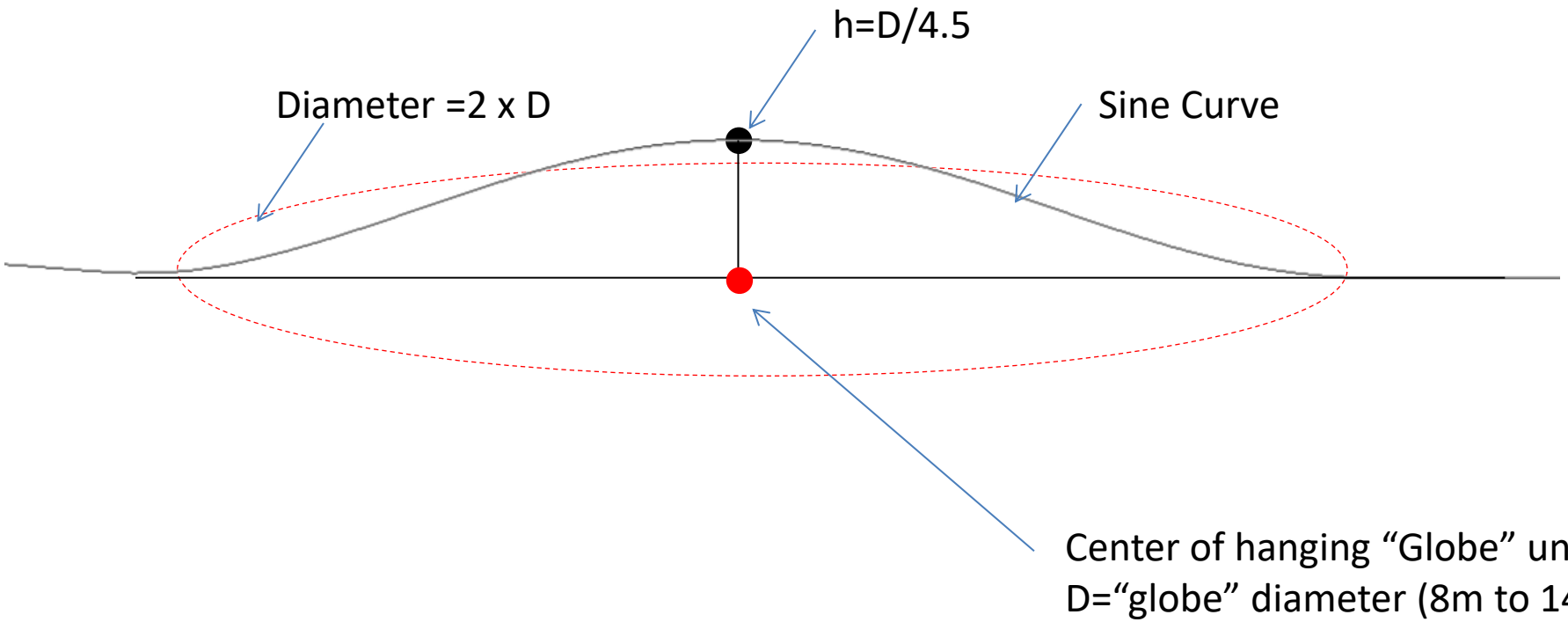


強軸

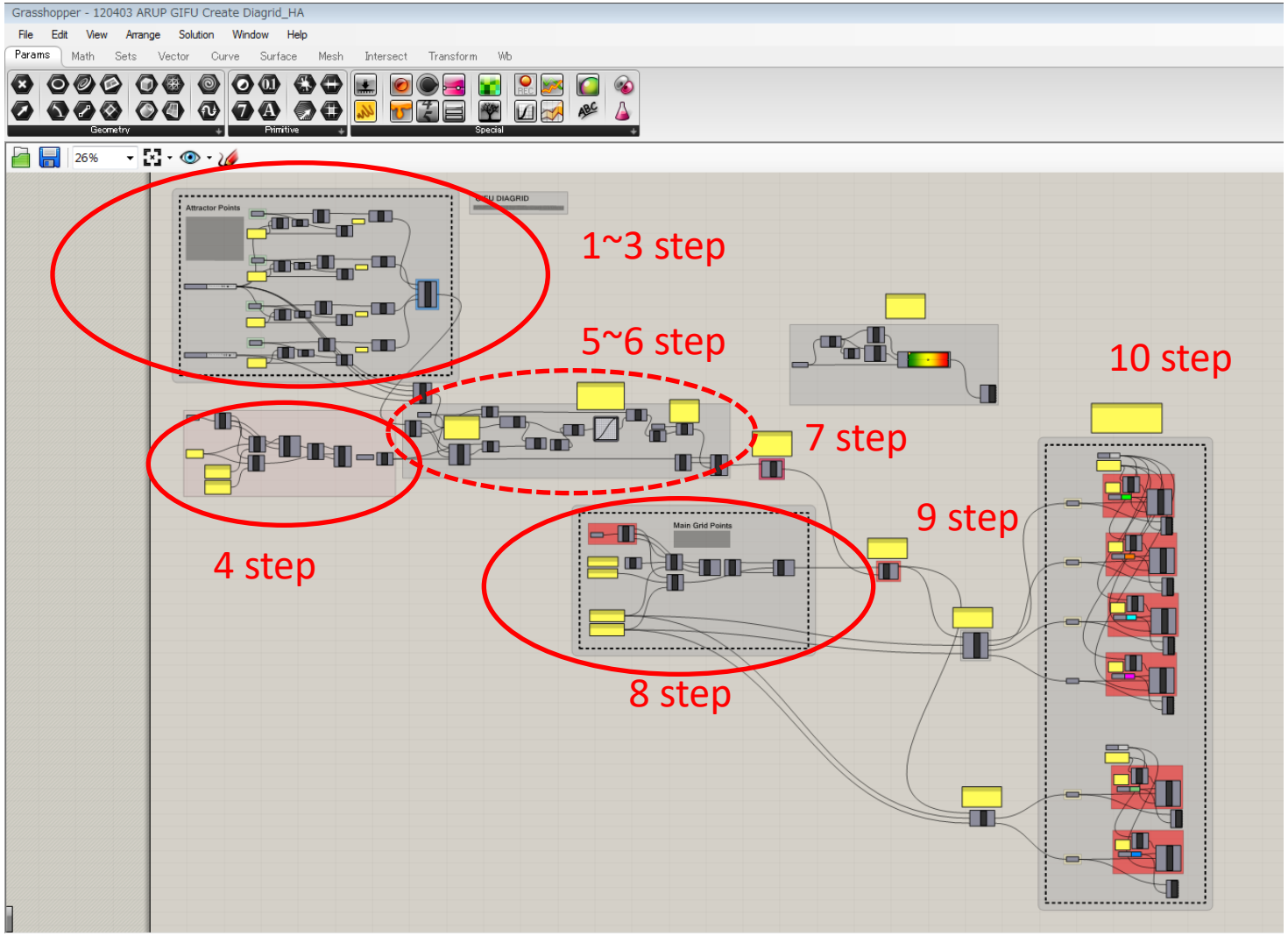


弱軸

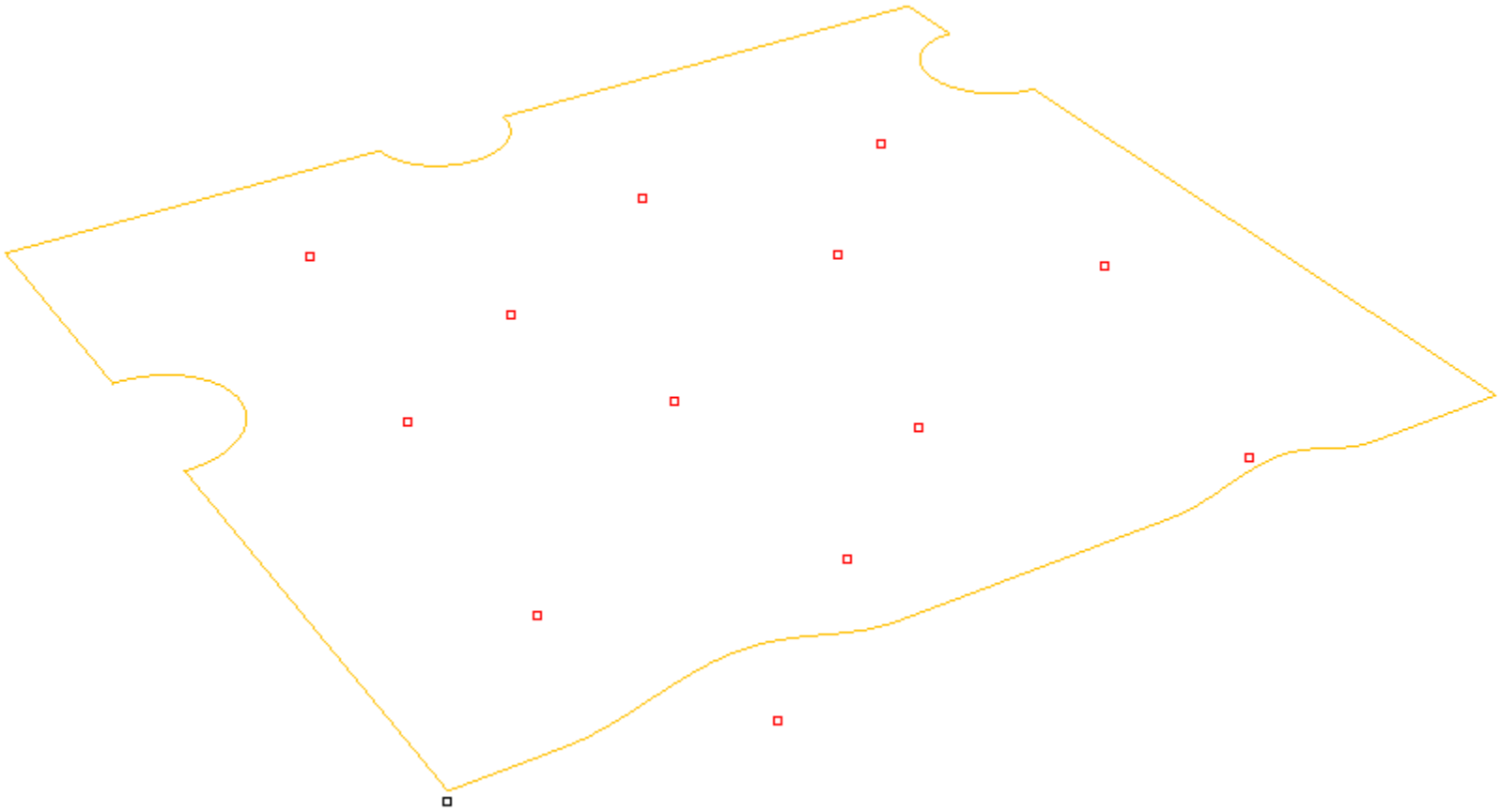
Geometry Definition Rule Proposed –Iterative Process



Roof geometry generation in 10 steps

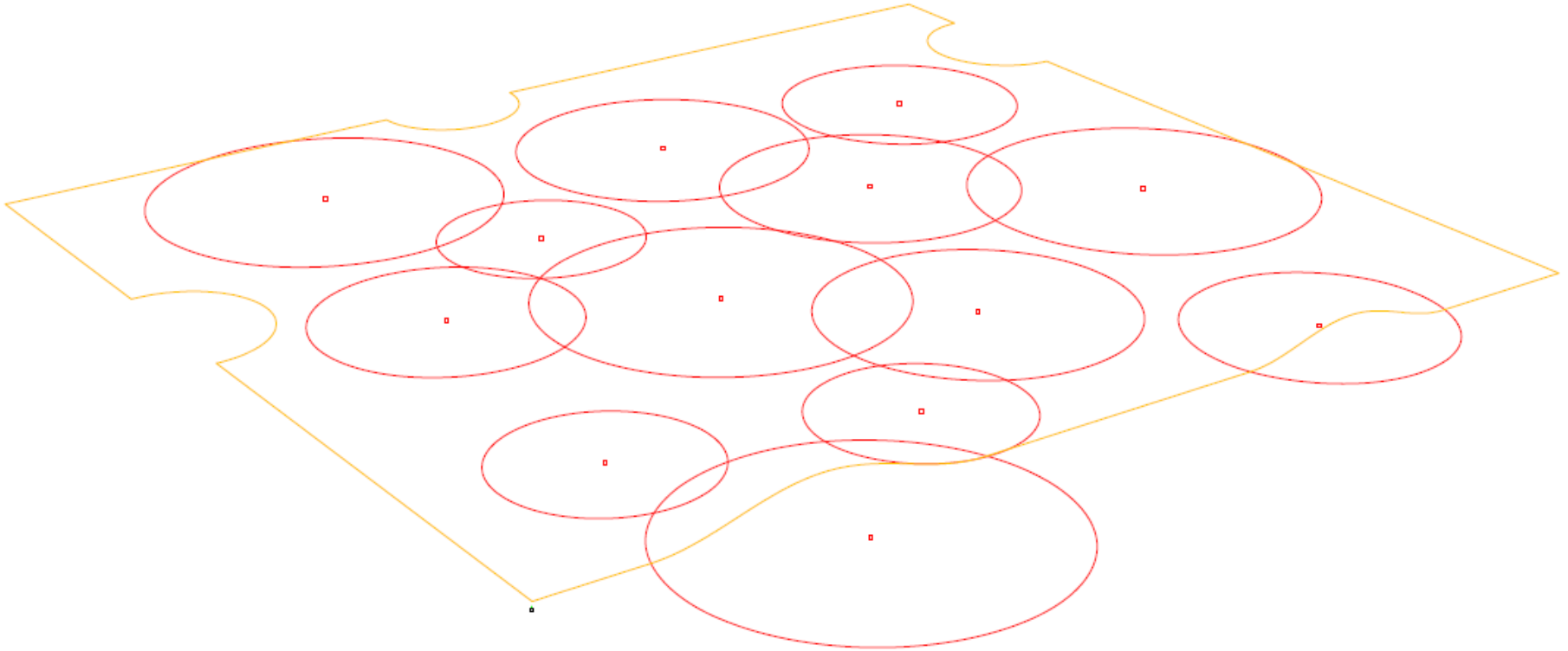


① Boundary condition and the center of the “globe” defined

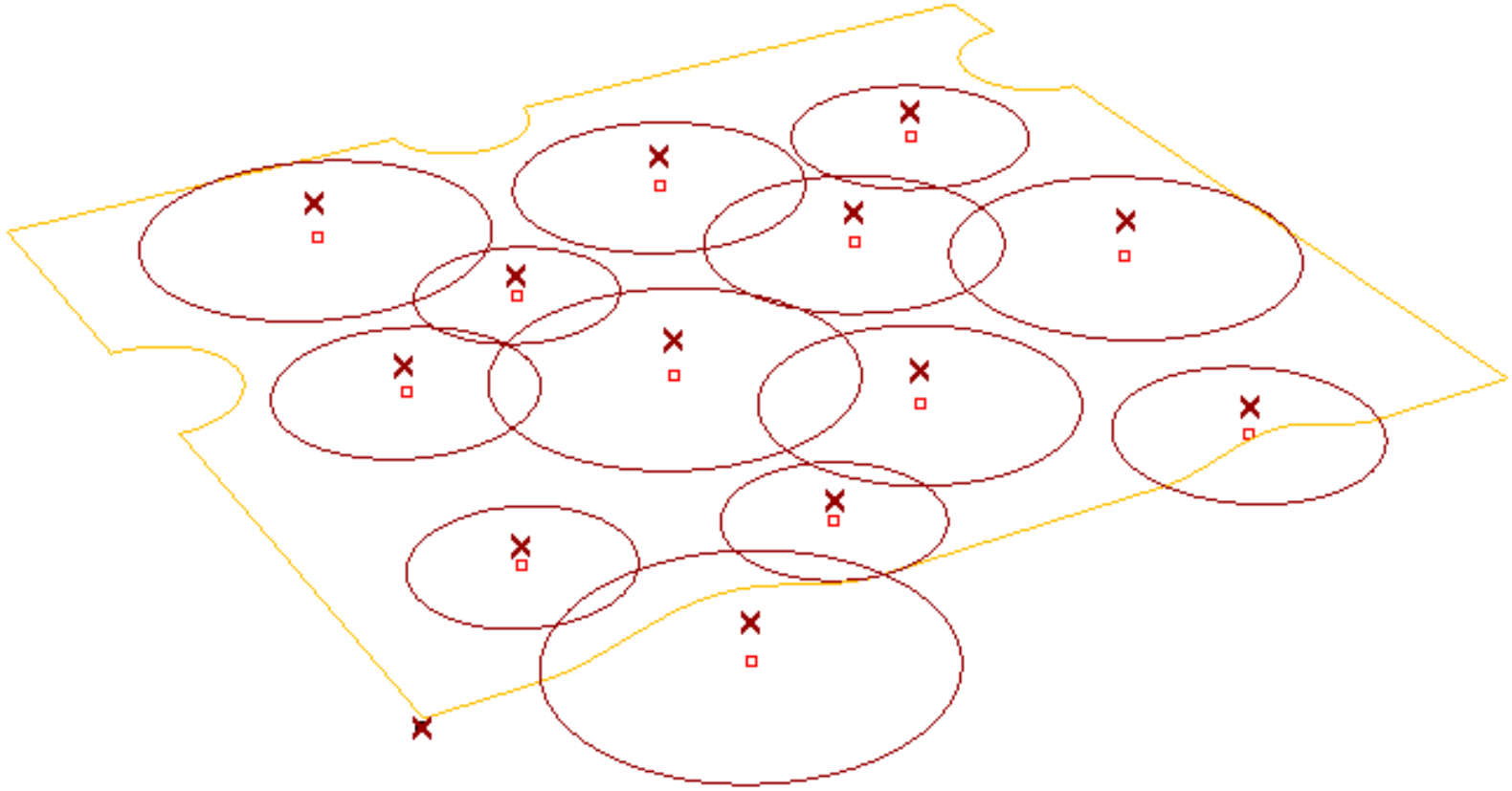


THIS IS THE ONLY INPUT ARCHITECTS DEFINE-KEEP IT SIMPLE

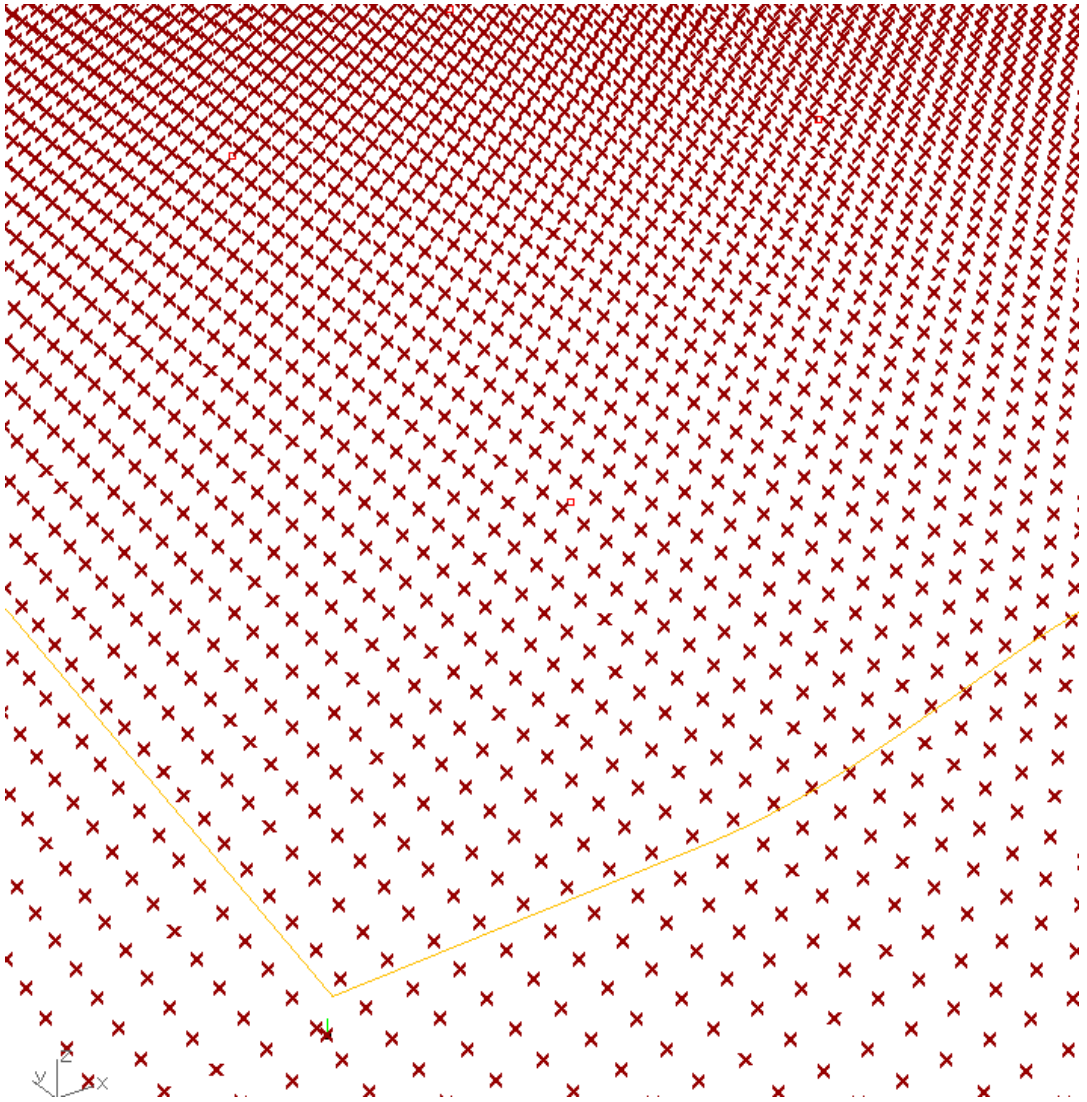
② Draw a circle with diameter of globe x 2.0



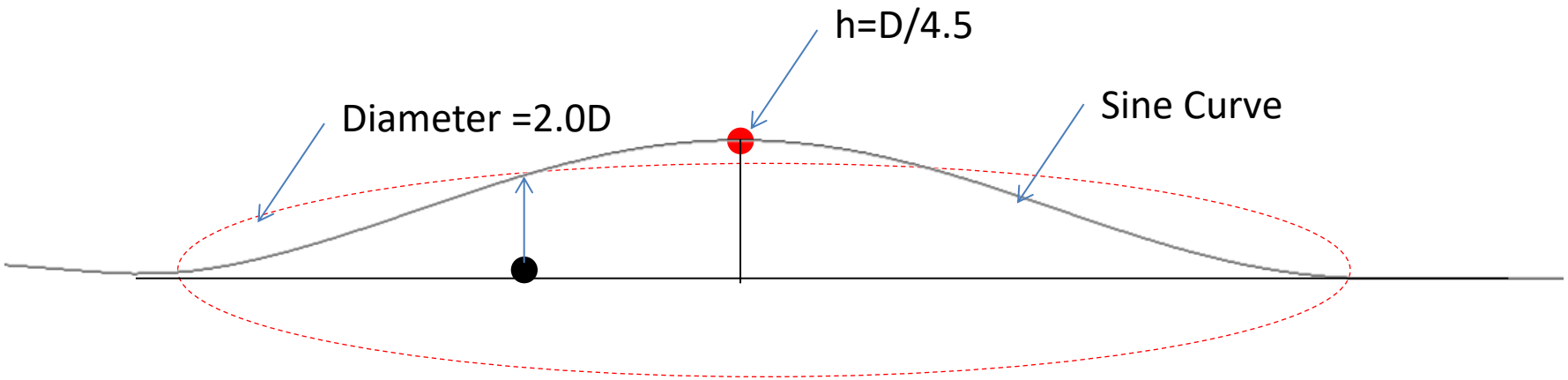
③ Z coordinate defined as globe diameter D÷4.5



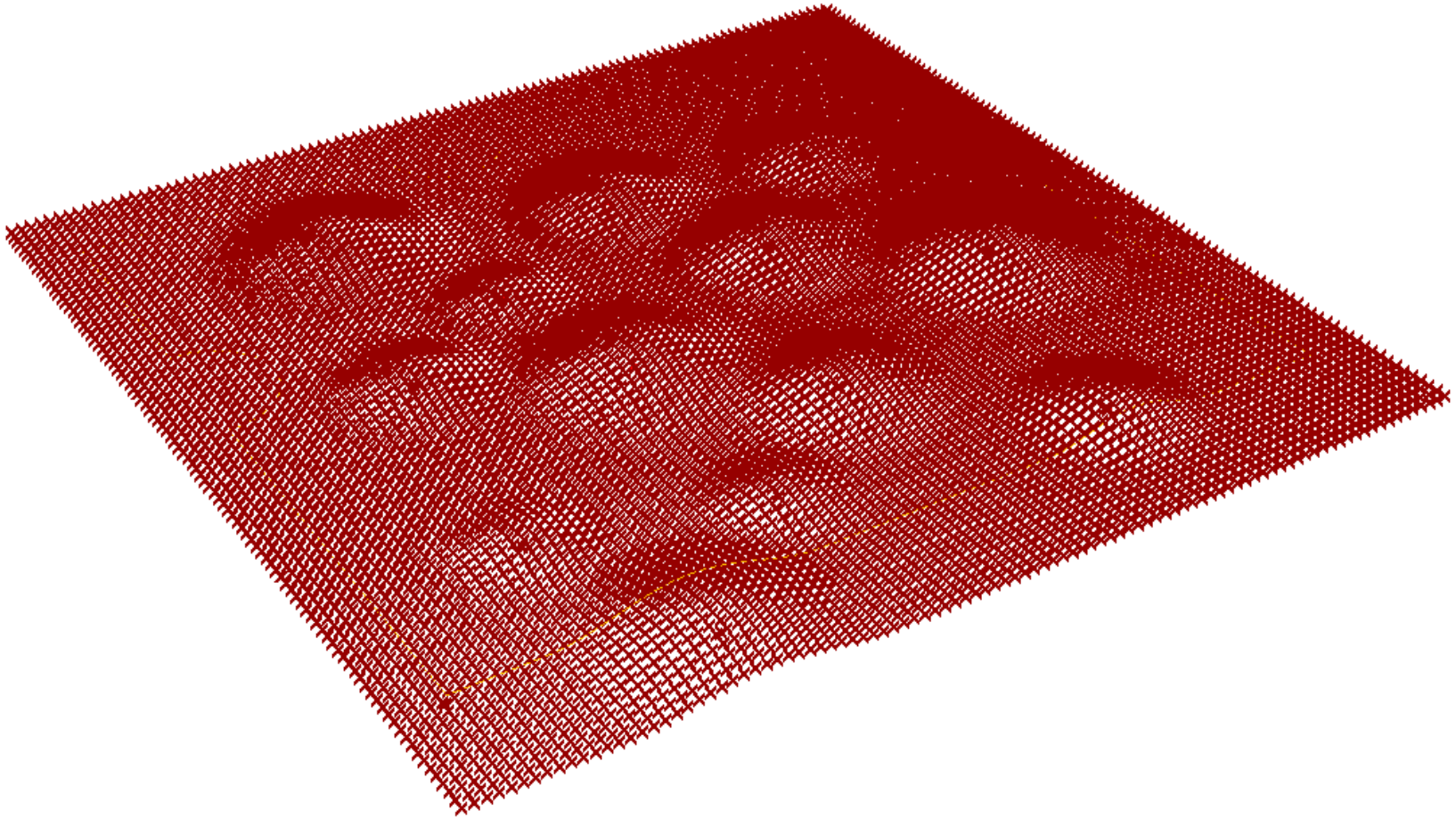
④ 1000mm×1000mm Grid node points laid out



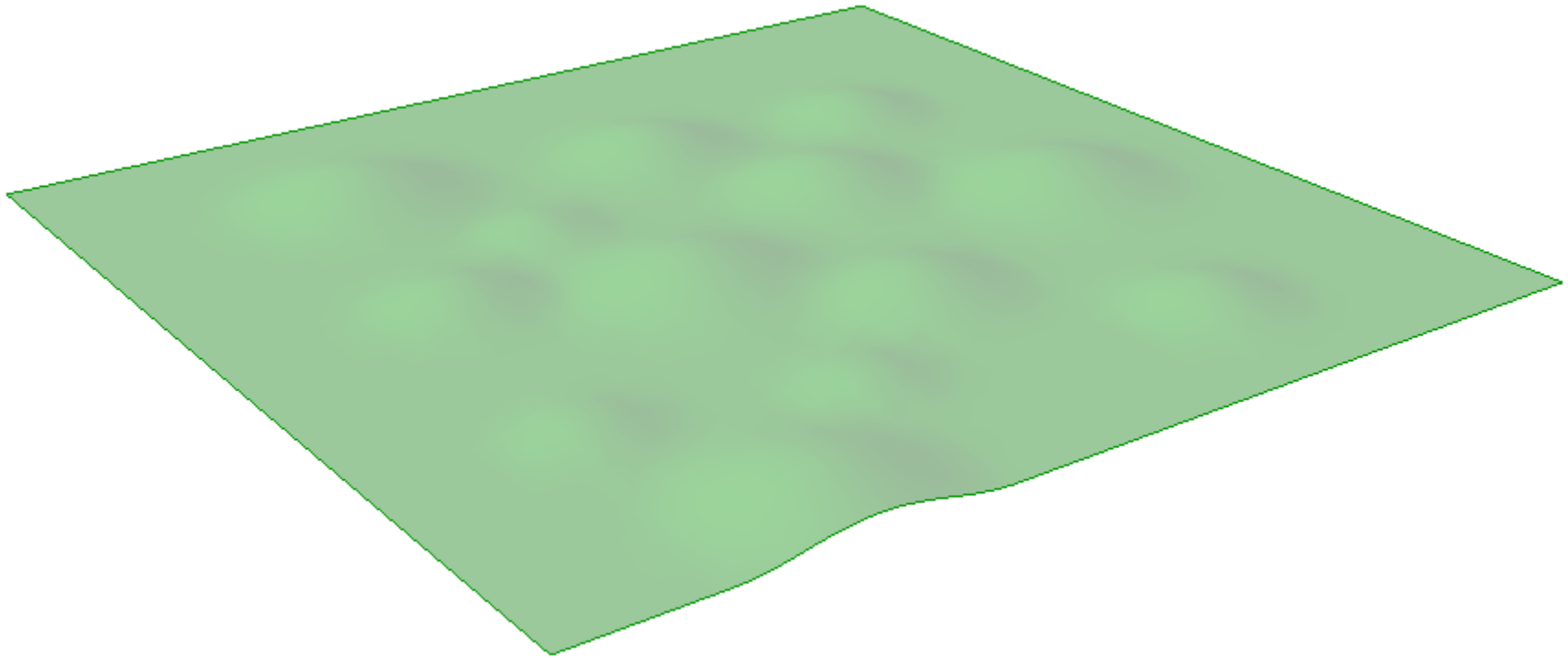
⑤ Sine curve defined as below



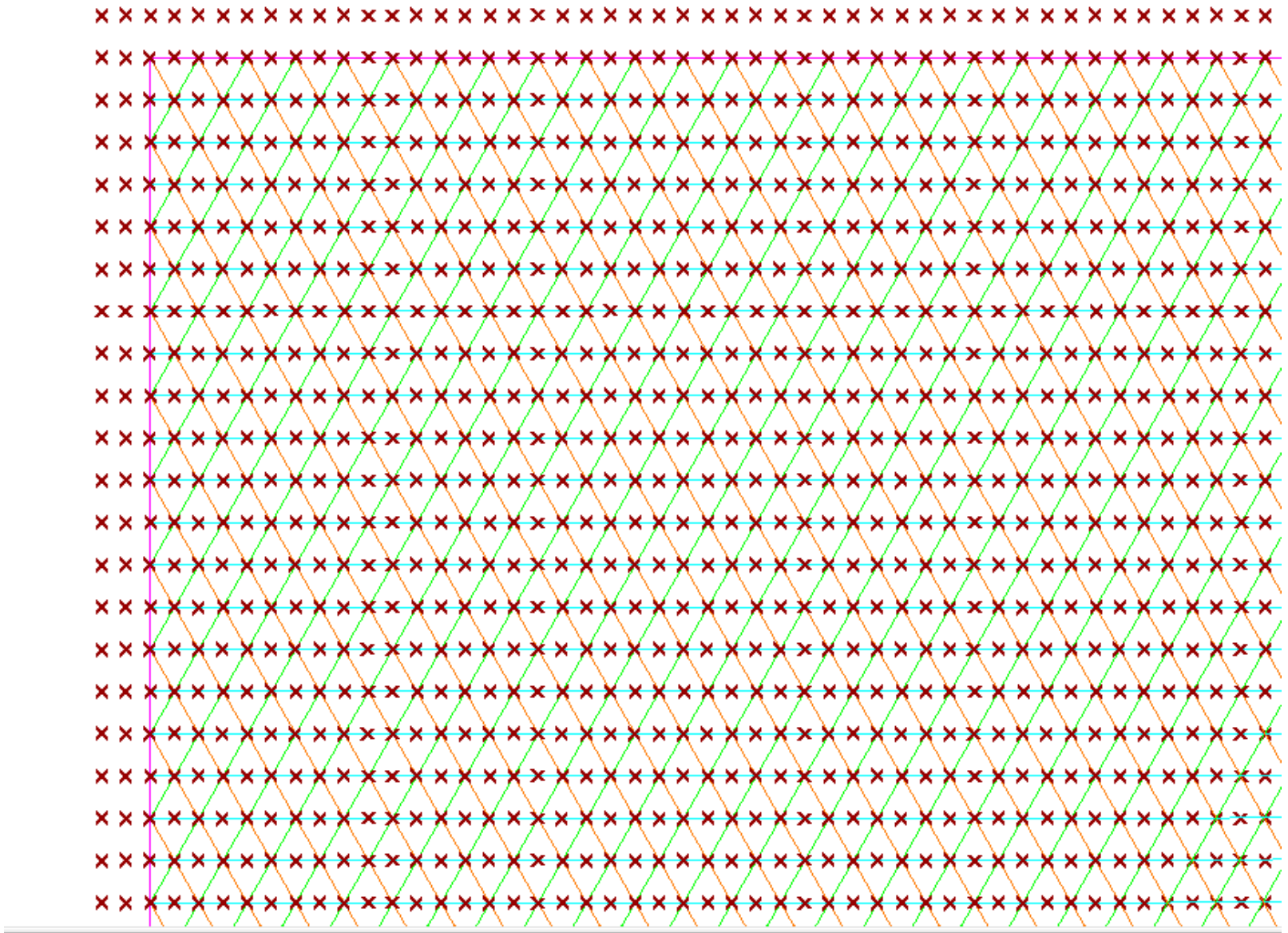
⑥ Determine Z coordinates for all 1000mm x 1000mm grid node points



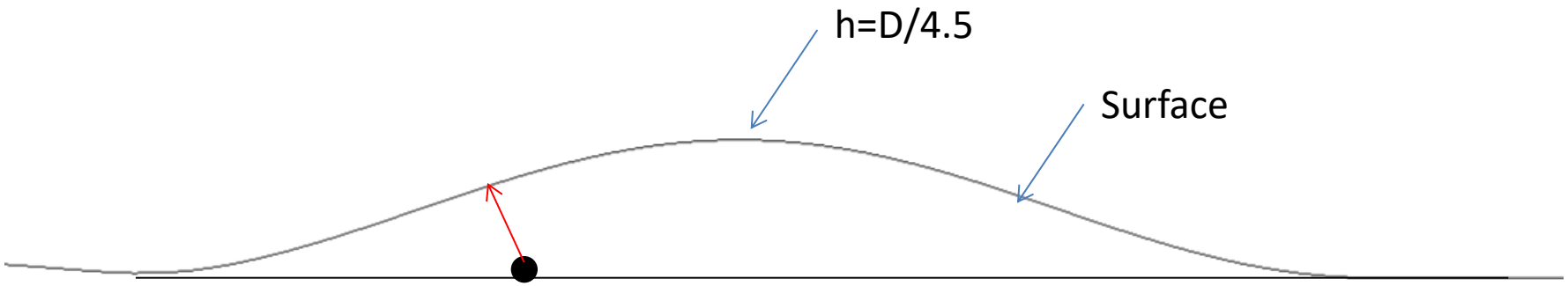
⑦ Create surface based on the grid points



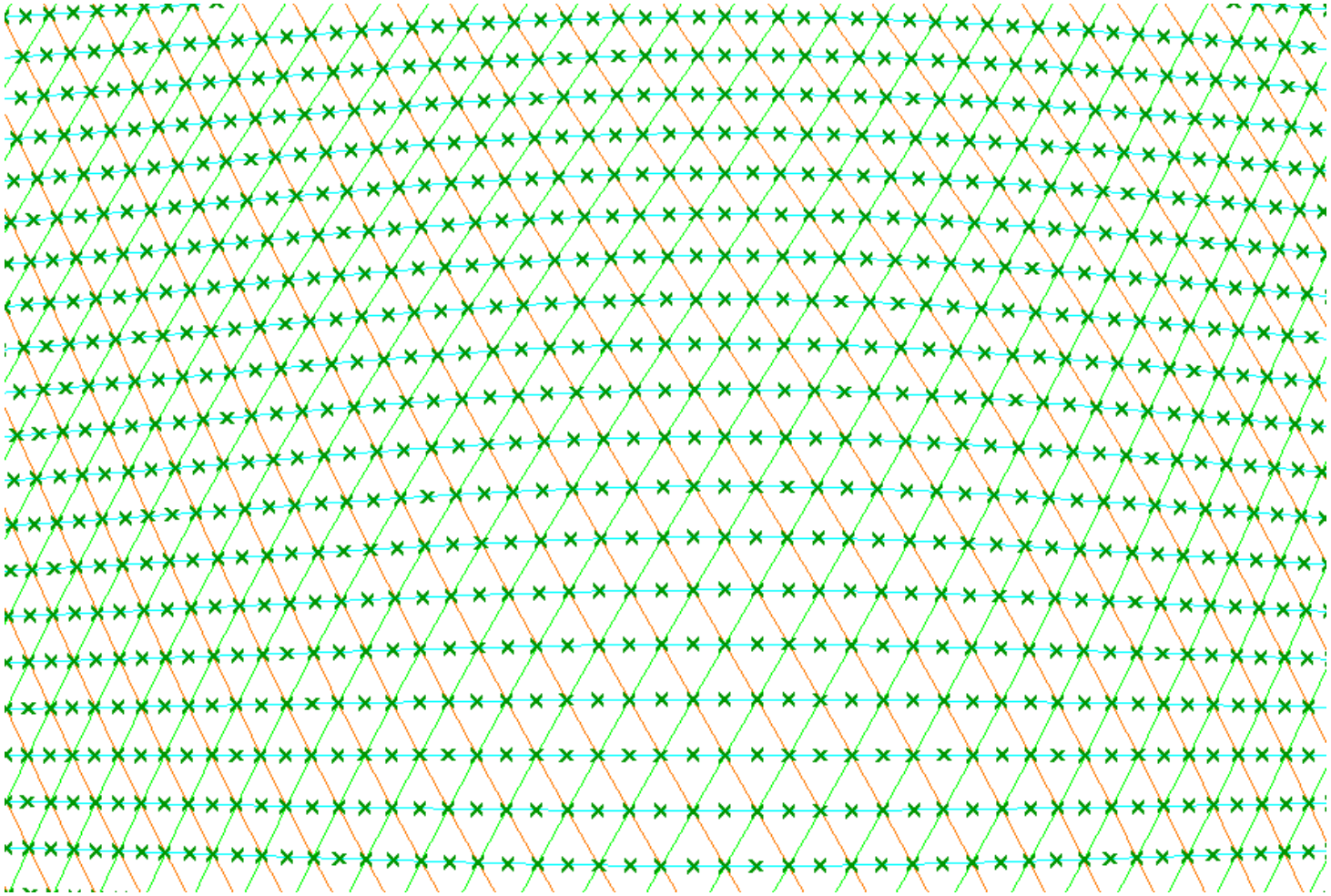
⑧ 400mm×460mm triangular grid Lines and intersections defined



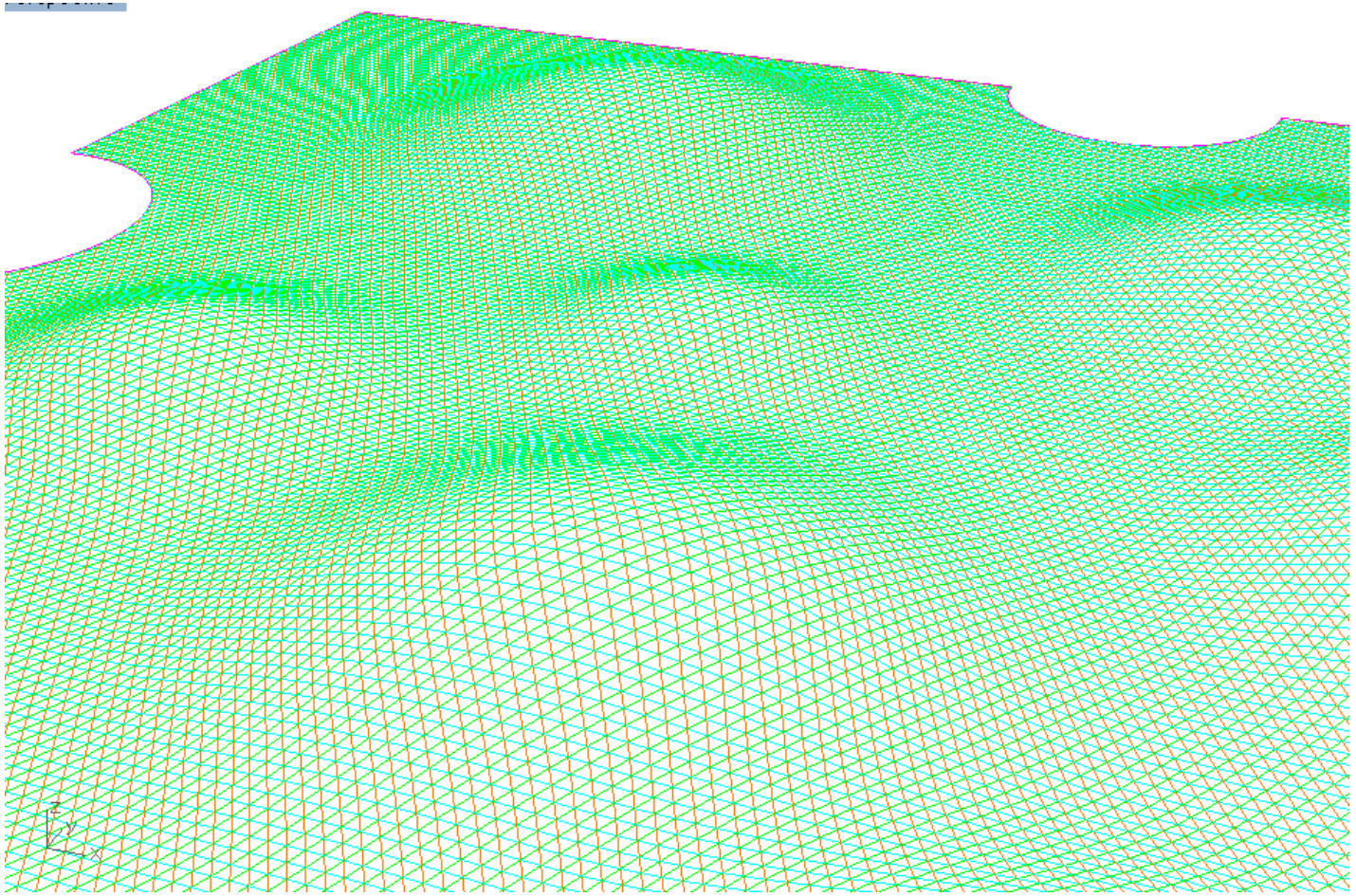
⑨ Nodes are projected normal to surface



⑩ Final grid connecting those projected points



⑩ Final grid connecting those projected points



If the form is not satisfactory, go back to Step ①

TESTING & FULL SCALL MOCKUPS

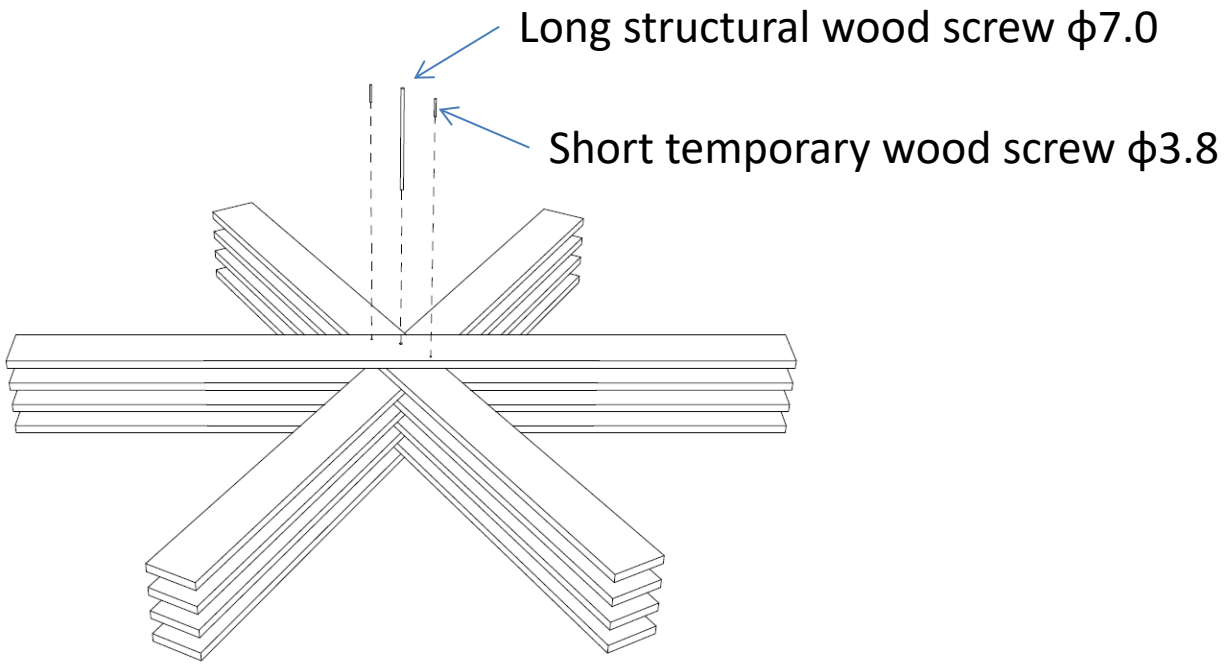
Constructability and Structural Performance

Mockup #1: bending and twisting straight planks

Layer by layer construction method development

12m (4m x 3, finger-jointed) plank is flexible enough

Mockup #1: bending and twisting straight planks




SAITO
工事名
工種
測点
長尺ビス実験
L=240,180


測点
ビス実験
240,180


ドリフトピン8本

Connection strength test

A：With steel plate（pins＋glue）

B：With steel plate（pins only）

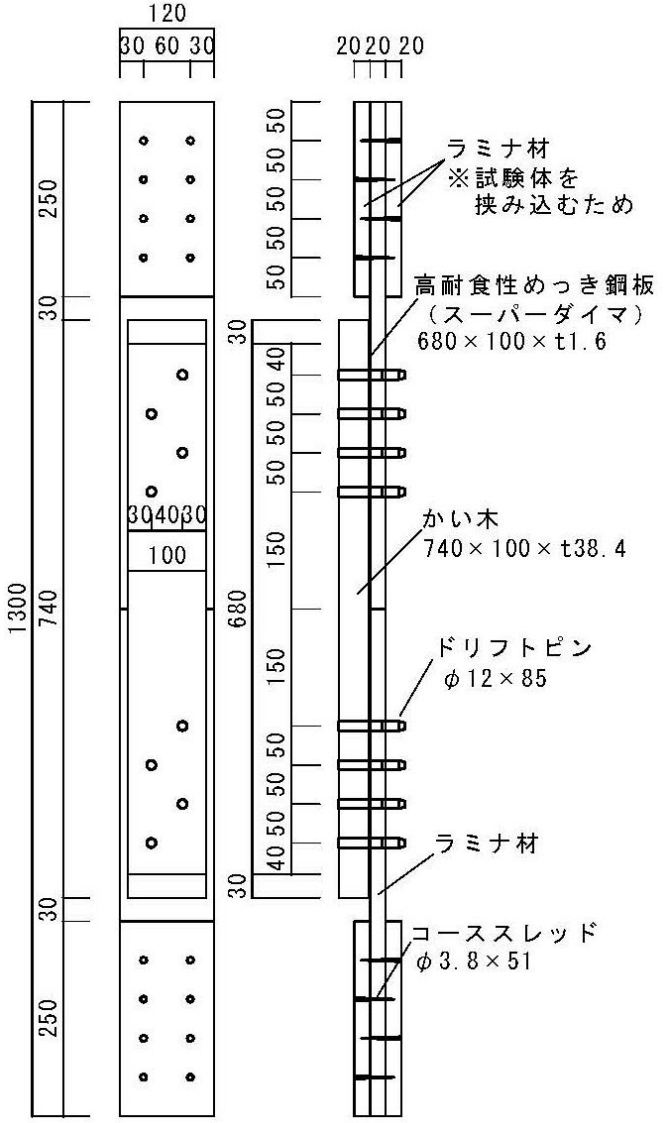
C：With steel plate（bolts＋glue）

D：Finger joint（with spacer）

E：Finger joint（no spacer）

F：No joint（with spacer）

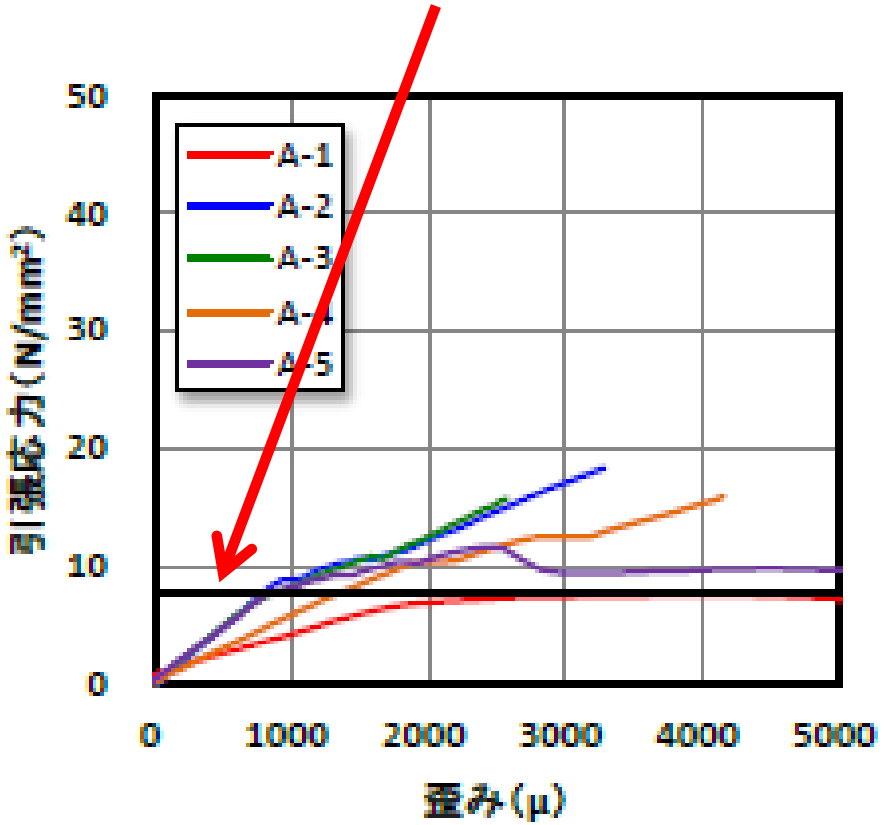
G：No joint（no spacer）



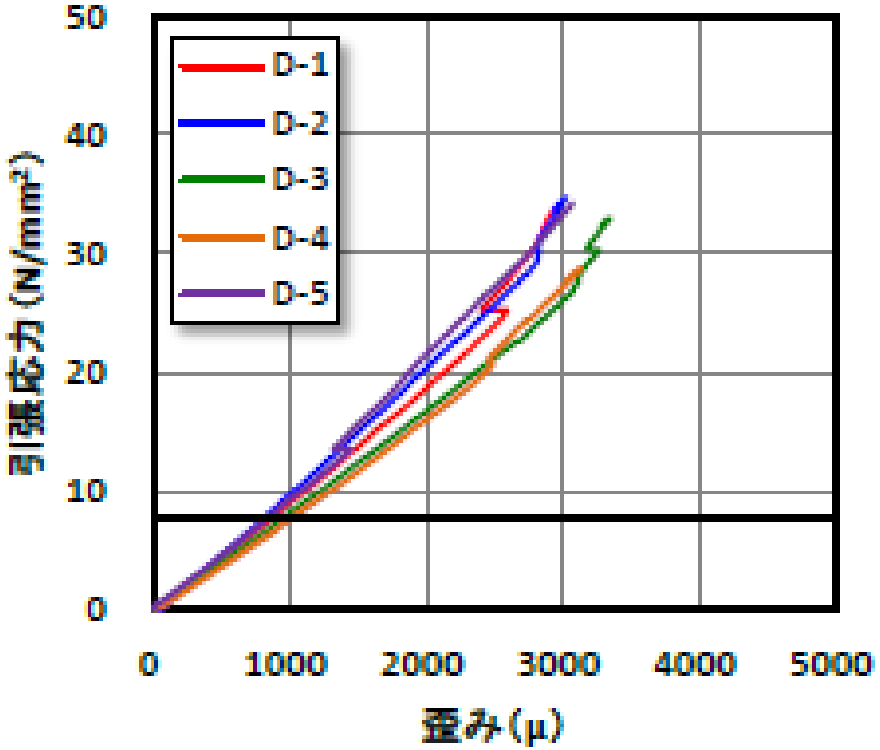
A：With steel plate（pins＋glue）

Connection strength test

Design strength 7.8N/mm2



A：Connection with thin steel plate with pins

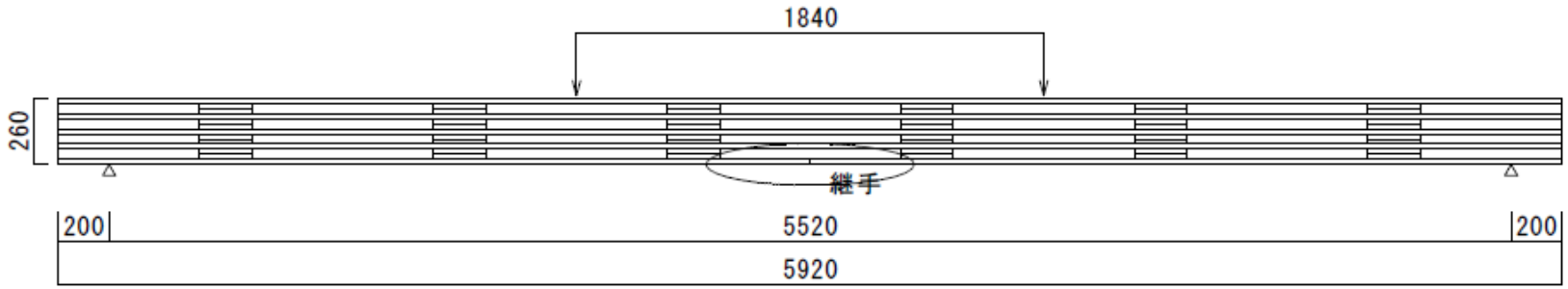


D：Finger joint (with spacer)

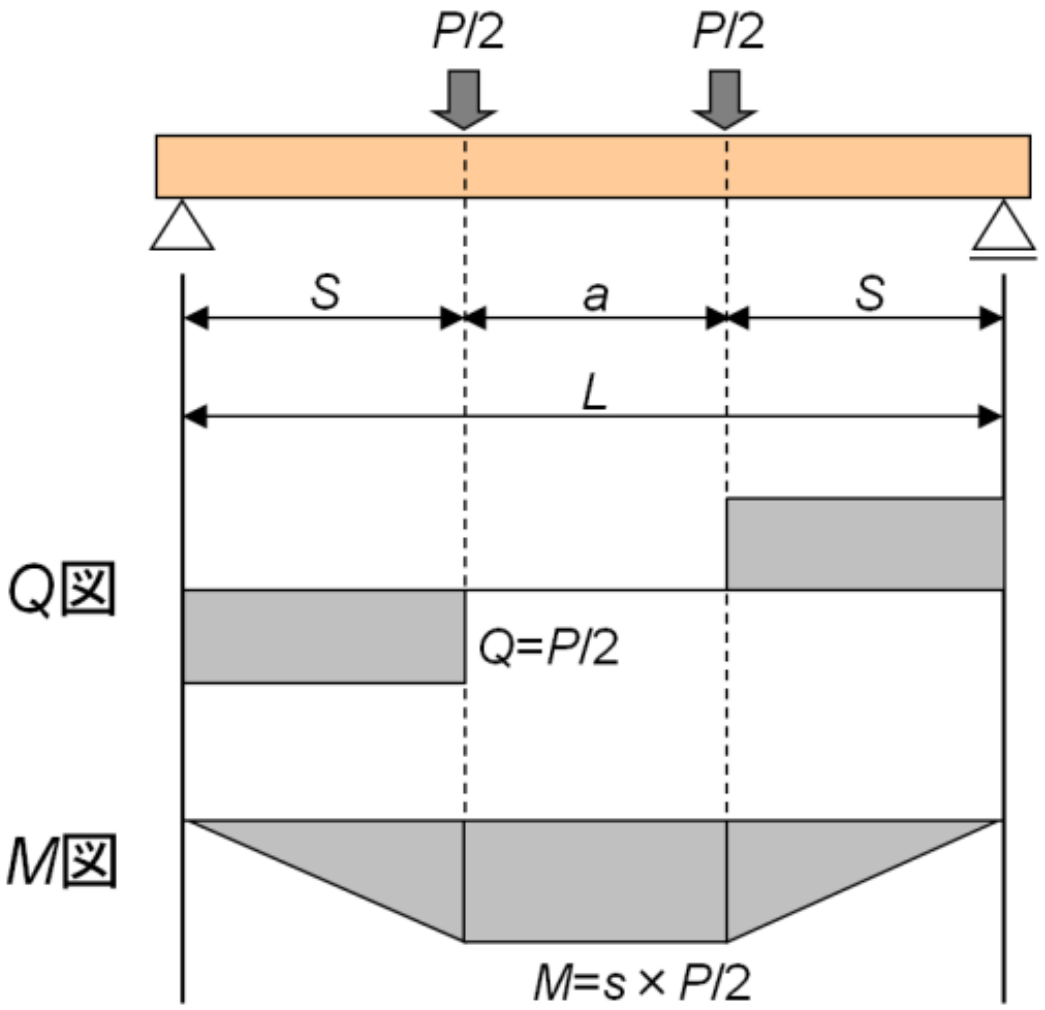
Bending test of layered element

Test summary

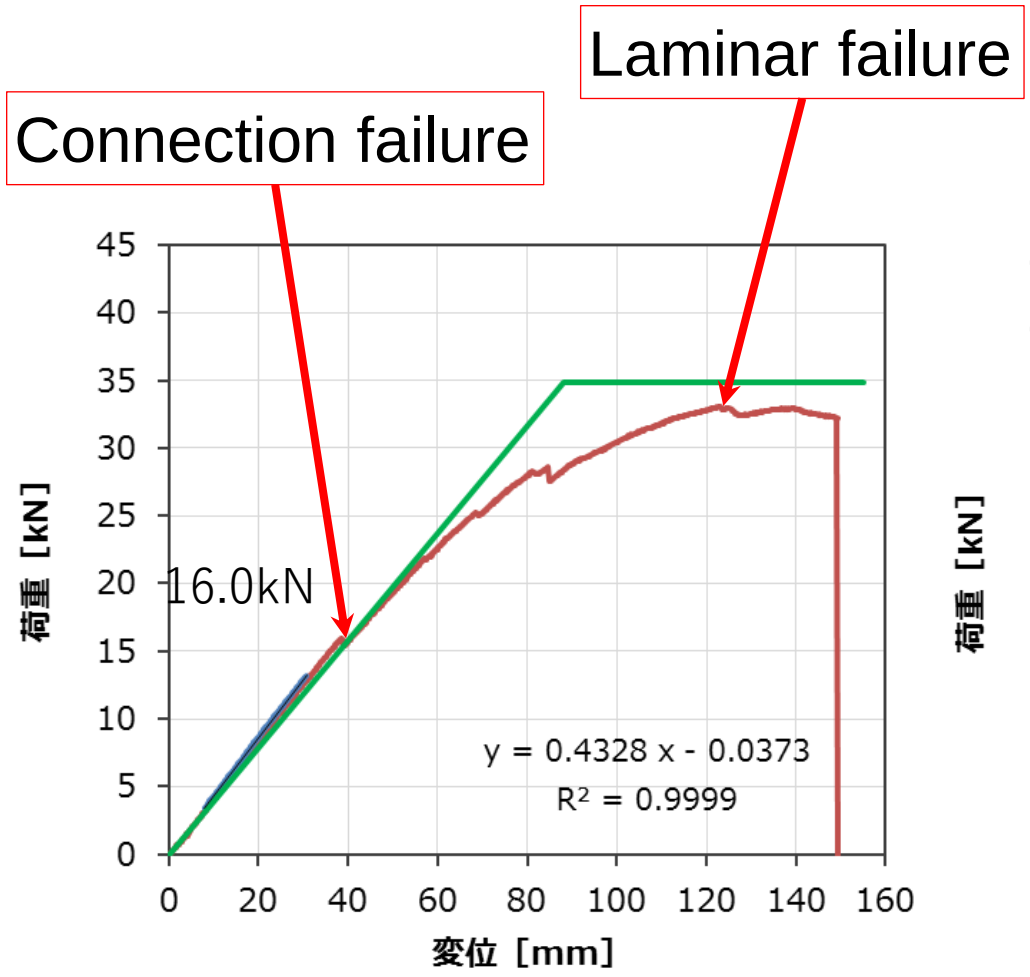
- Element types： WB5, WB7 2 types (5 layers, 7 layers9
- No of tests： 3 specimens each, total 6 specimens
- Joint type： Type A With steel plate（pins＋glue）
- Joint location： Lowest or highest layer, centered
- Loading： at 2 points in center（600mm between 2 points）
- Test span： WB5：5.52m（element depth x 21），
  WB7：7.36m（element depth x 19）



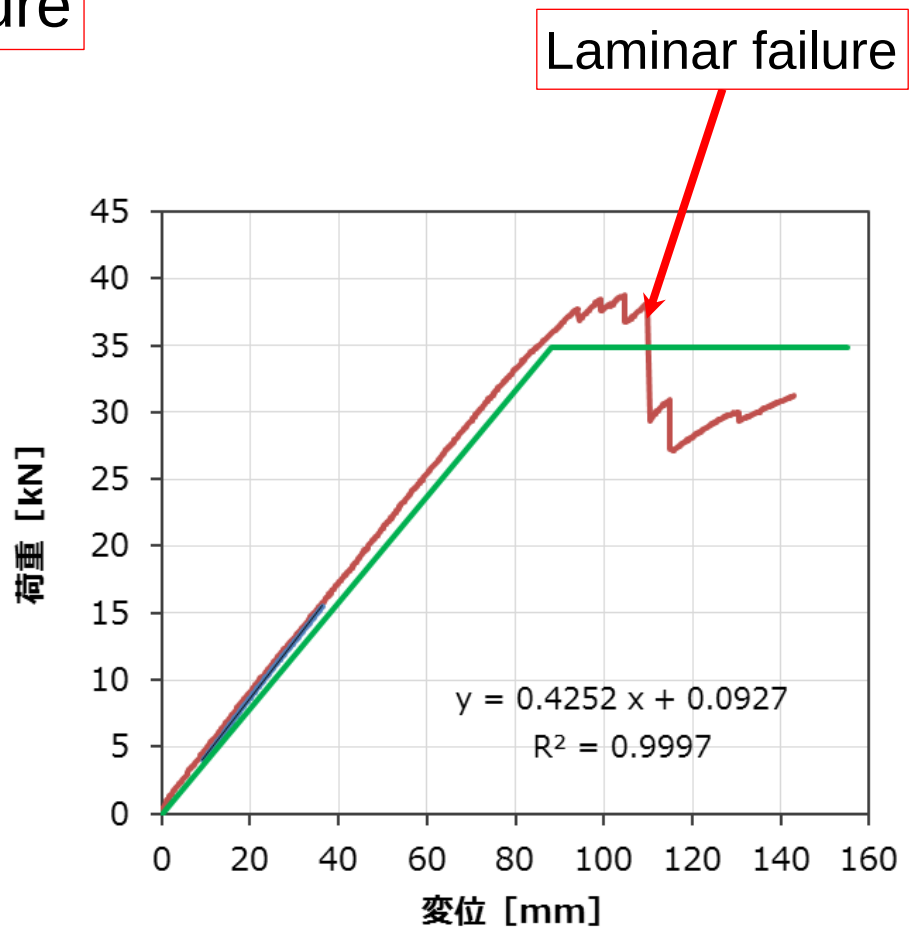
Bending test of layered element



Bending test of layered element



Connection at bottom layer

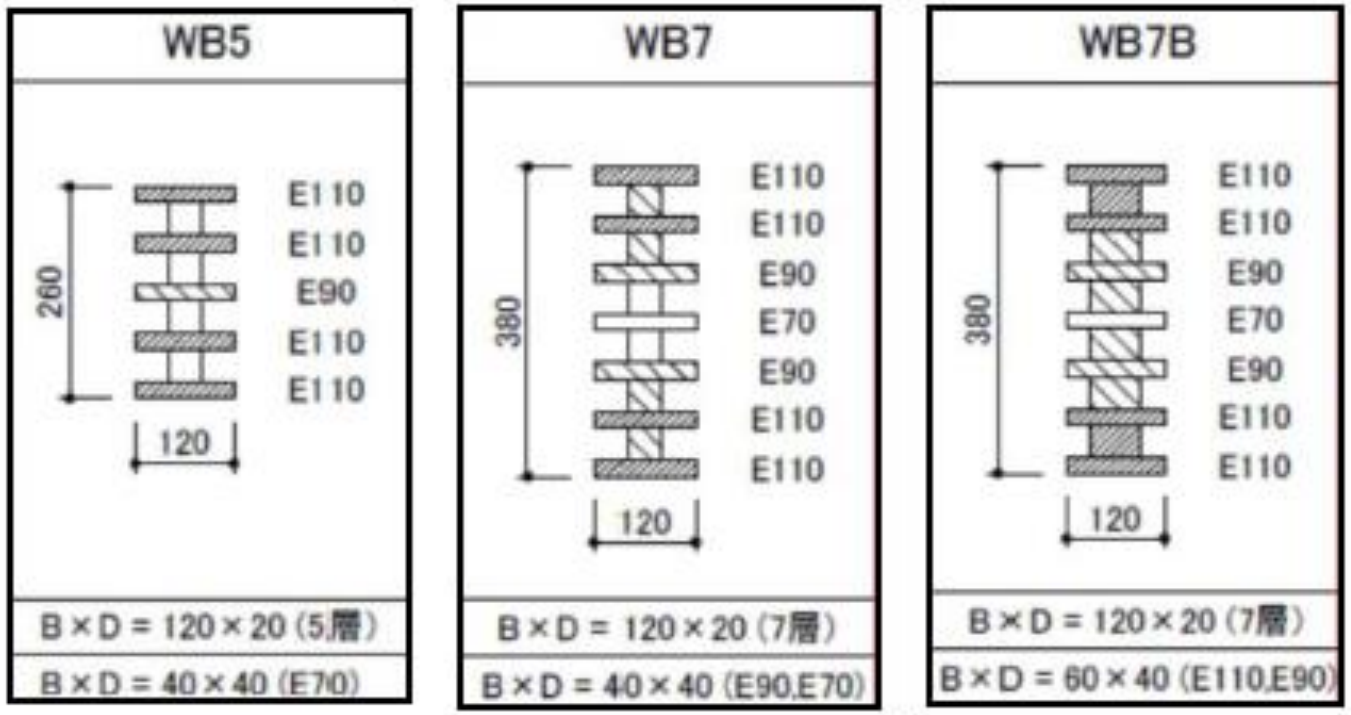


Connection at top layer

Creep test

Test Summary

- Test element types： WB5, WB7, WB7B
- No of Specimens： 3 specimens for each type
- Specimen length： 4m（support distance3.8m）
- Long-term load : 40% of maximum strength form test



Creep test

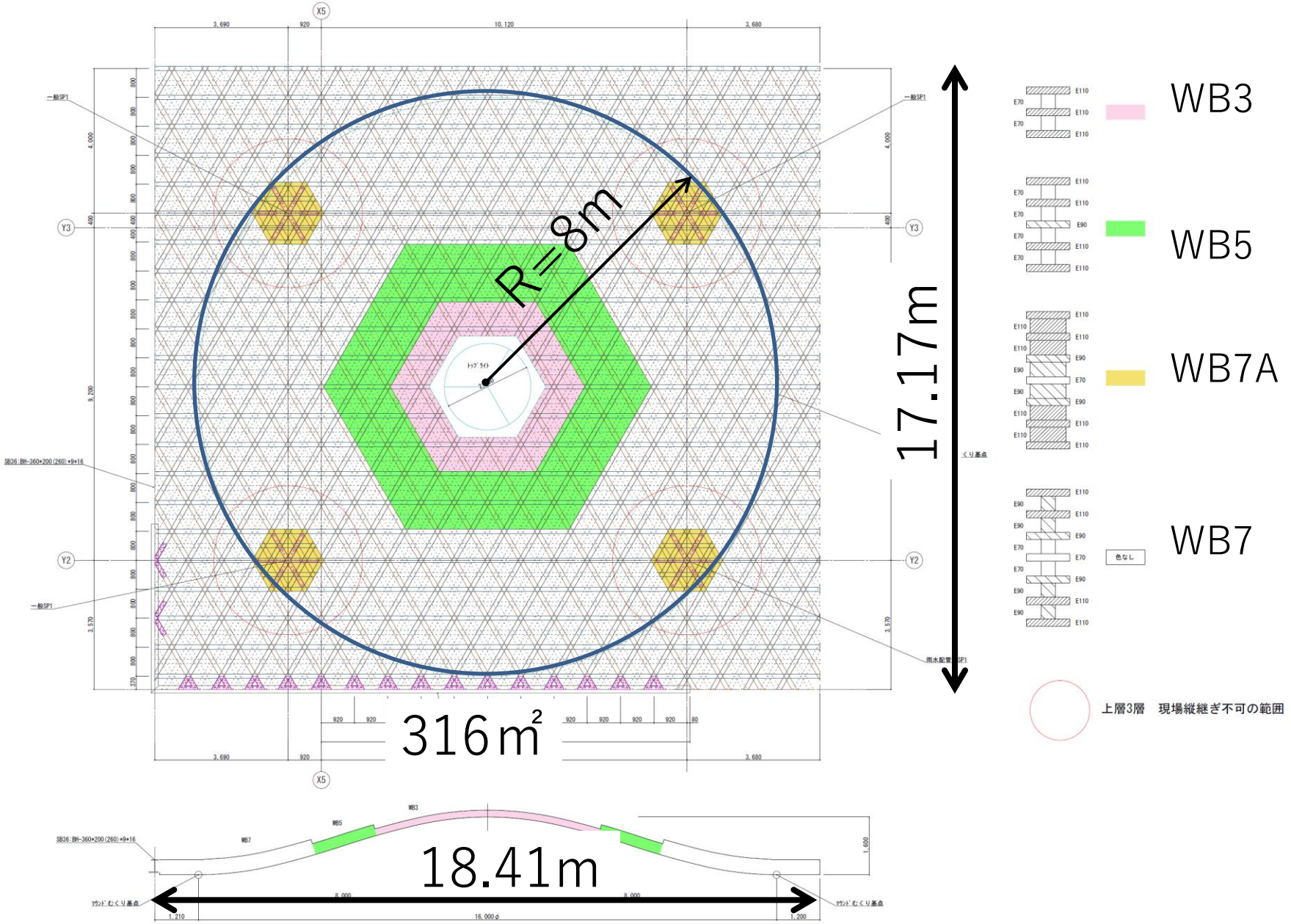
No.	δ_{1min}	傾きf	切片e	δ_{50year}	C_{cp}	K_{50year}
WB5-1	15.57	-0.005	-0.006	17.29	1.11	0.90
WB5-2	15.24	-0.056	0.183	26.16	1.72	0.58
WB5-3	17.58	-0.076	0.249	36.58	2.08	0.48
平均値					1.64	0.65
WB7-1	8.62	-0.011	0.014	10.10	1.17	0.85
WB7-2	9.18	-0.060	0.198	16.26	1.77	0.56
WB7-3	9.91	-0.093	0.310	23.76	2.40	0.42
平均値					1.78	0.61
WB7B-1	10.99	-0.014	0.023	13.28	1.21	0.83
WB7B-2	10.60	-0.047	0.156	16.62	1.57	0.64
WB7B-3	10.40	-0.088	0.292	23.88	2.30	0.44
平均値					1.69	0.63

※δ_{1min}：1分後の中央たわみ（mm）、f：$\log_{10}K_t$と$\log_{10}t$の回帰直線の傾き、e：$\log_{10}K_t$と$\log_{10}t$の回帰直線の切片、δ_{50year}：50年後の中央たわみの予測値（mm）、C_{cp}：50年後のクリープ係数（$=\delta_{50year}/\delta_{1min}$）、$K_{50year}$：荷重継続時間50年に対するクリープたわみ比の予測値（$=\delta_{1min}/\delta_{50year}$）。

Obtained creep coefficient for 50 years

Mockup #2: Real design and load testing

Mockup #2: Real design and load testing



Mockup #2: Real design and load testing

Design
- Deflection due to self weight, additional weight
- All the connection details
- Effect of water and UV during construction

Construction
- Establishing construction rule among the leaders
- Buildability and safety of scaffolding
- Jack-down sequence

Included façade, globe, floor, etc

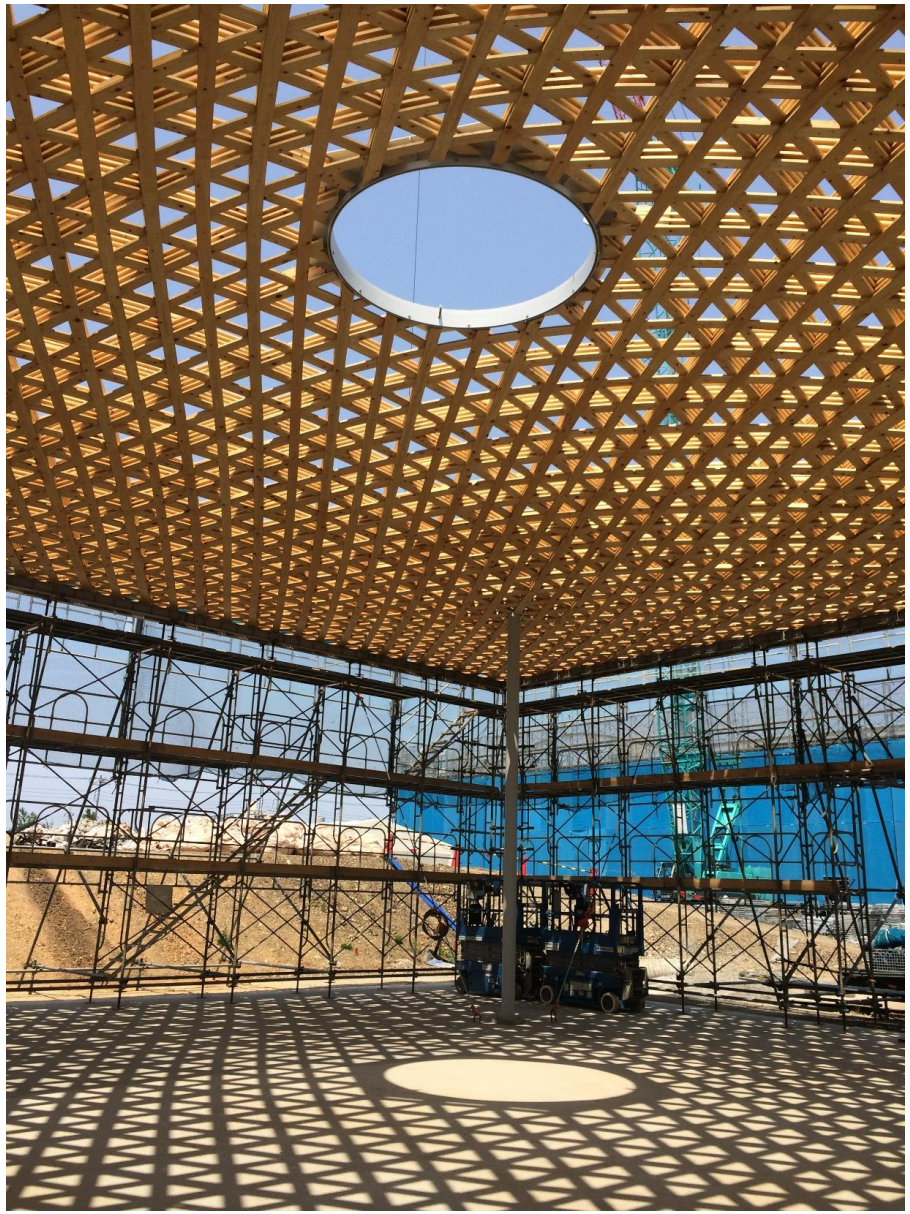
Façade mockup

Mockup #2: Real design and load testing

Weight applied, maintained, and removed

Repeated and measured deflection

→Decided not to camber the roof



CONSTRUCTION

Contractor: Toda Corporation

Concrete shell structure near site built by Toda Corporation

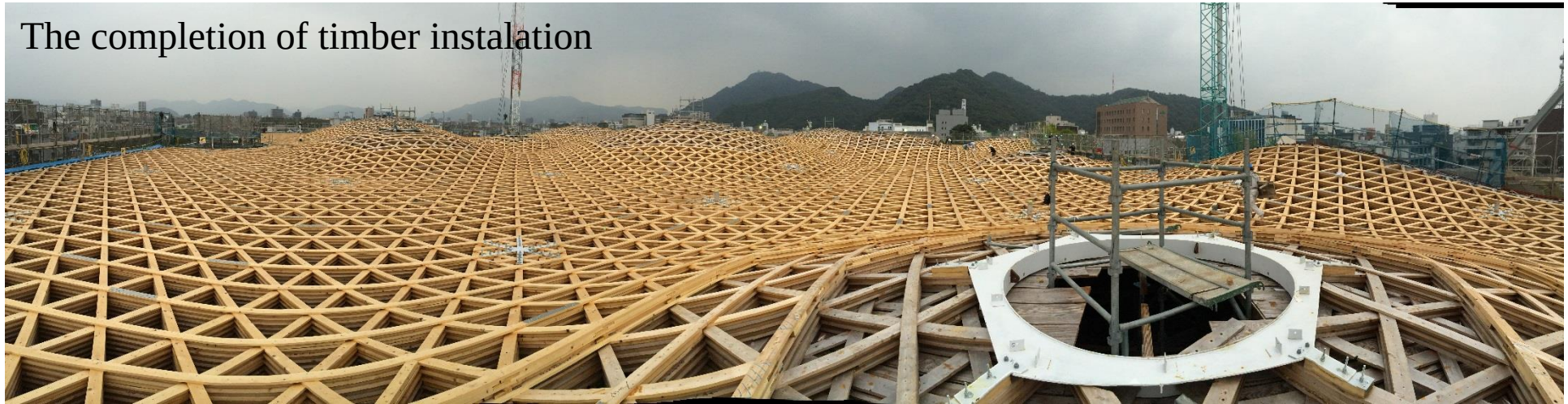
Form work before first layer application

50% of the roof is designed to be flat for economy

Marking the grid geometry, 23,000 points

Layer #8 construction
150 carpenters on the roof


The instalaton of first planks


The completion of timber instalation

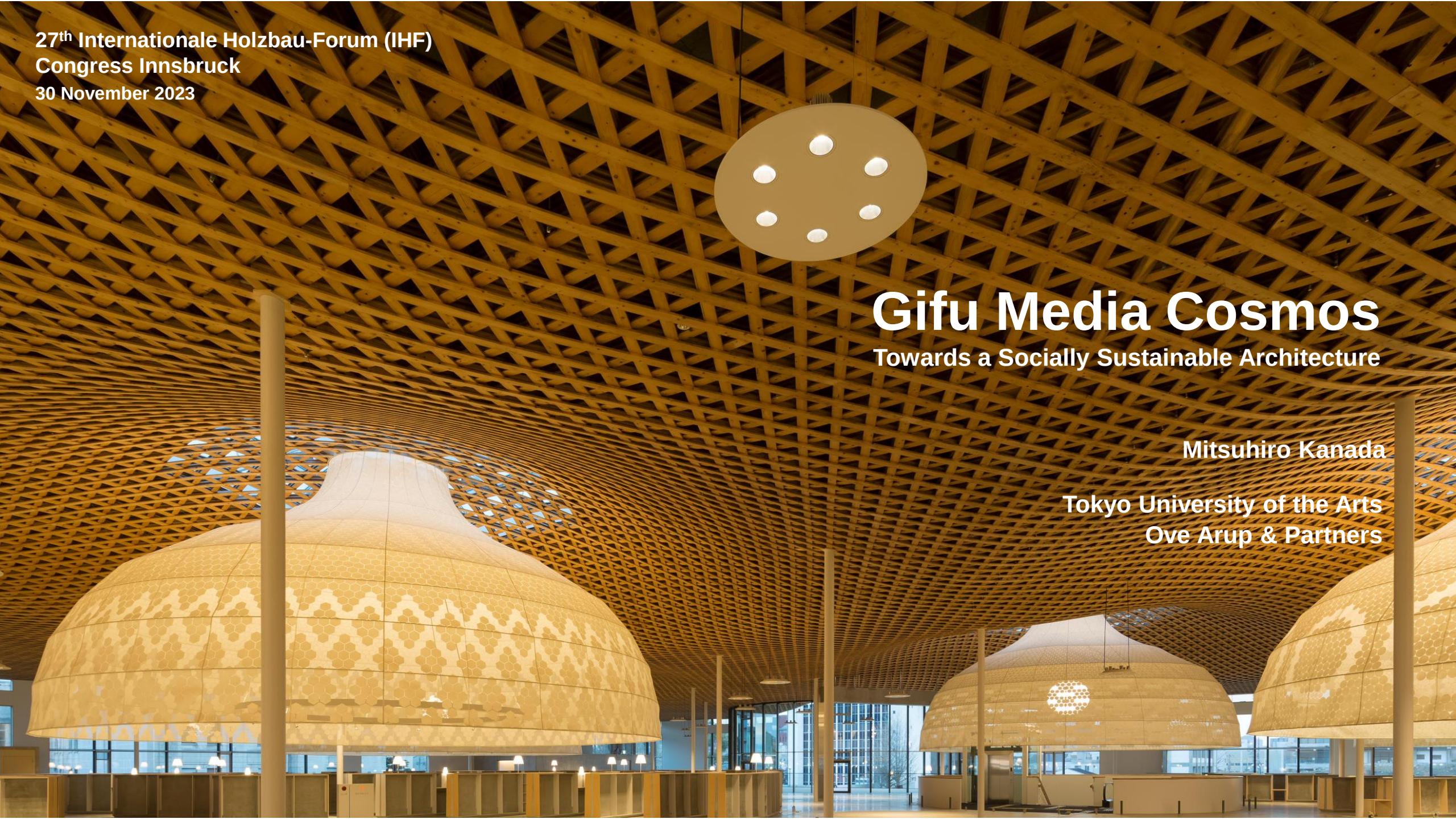
150 local carpenters built this timber roof in 100 days.
They are all proud owners of this library, living near by, supporting its future.

FOCUS ON PEOPLE

Timber as catalyst for community building, it is not just about carbon
Aiming a long lasting and beloved architecture

Socially Sustainable Way of Building

27th Internationale Holzbau-Forum (IHF)
Congress Innsbruck
30 November 2023



Gifu Media Cosmos

Towards a Socially Sustainable Architecture

Mitsuhiro Kanada

Tokyo University of the Arts
Ove Arup & Partners

1400 years

Horyuji Temple Pagoda 7th century
Height: 32m

Sumitomo Forestry W350, planned for 2041
Height: 350m