Integrated computational approach for the generation and preliminary structural analysis of woven structures during the early design stage

Nikoletta Christidi | 4738594
Mentors: Serdar Aşut, Peter Eigenraam

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RESEACH FRAMEWORK

INTRODUCTION TO WEAVING

COMPUTATIONAL TOOLS

CASE STUDY

CONCLUSIONS

1 RESEACH FRAMEWORK

2 INTRODUCTION TO WEAVING

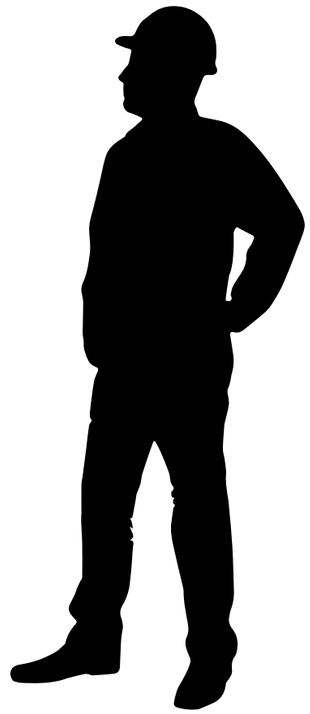
3 COMPUTATIONAL TOOLS

4 CASE STUDY

5 CONCLUSIONS

1 2 3 4 5

PROBLEM STATEMENT



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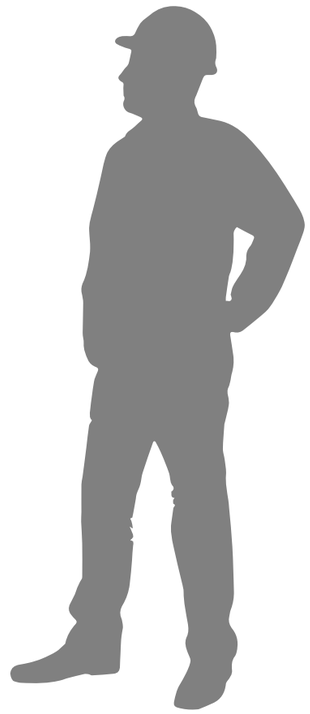
PROBLEM STATEMENT



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PROBLEM STATEMENT

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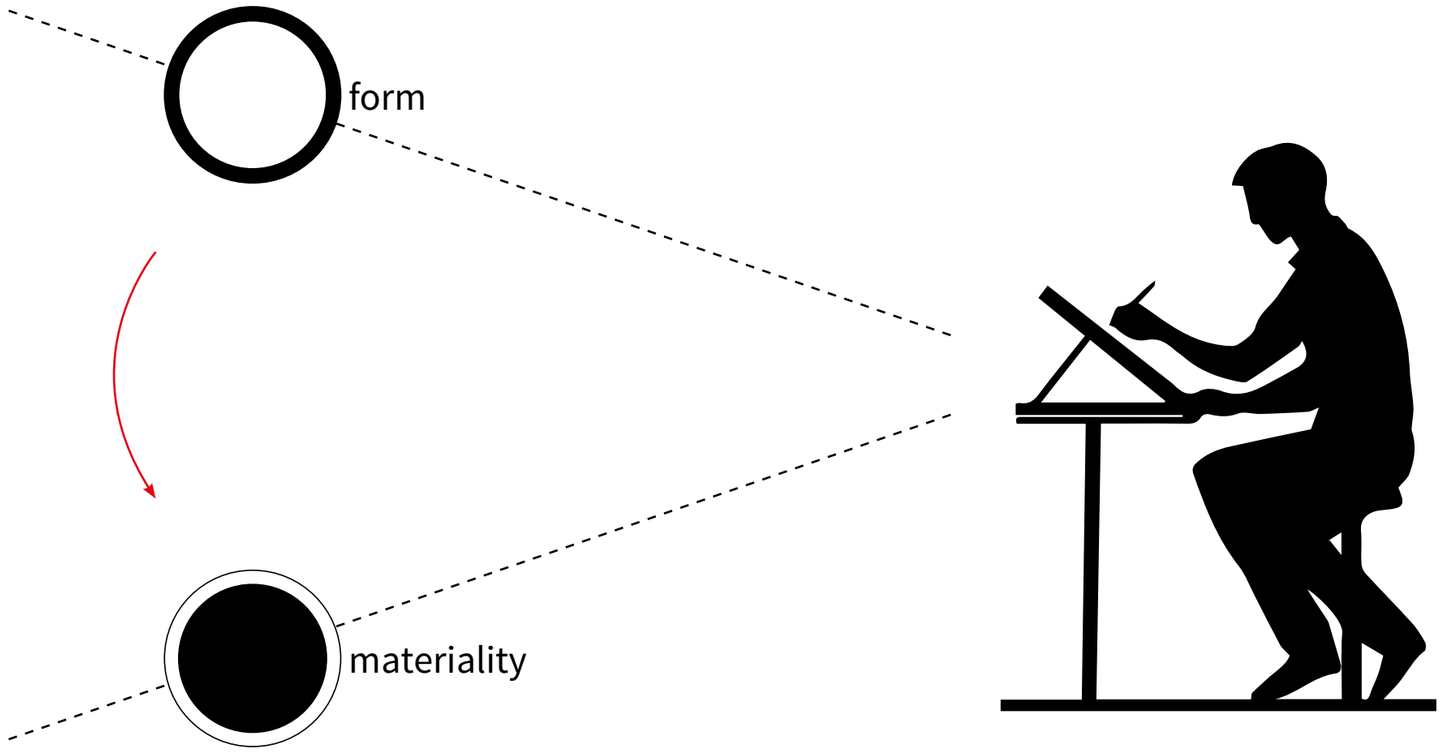

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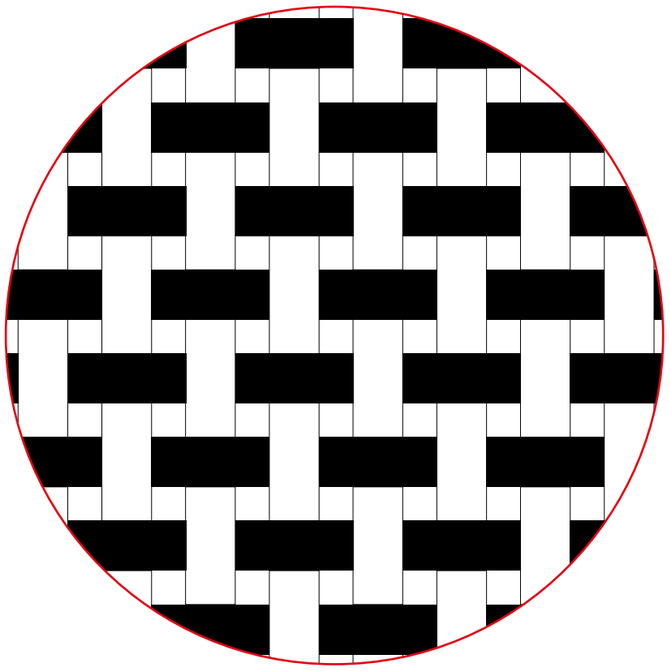

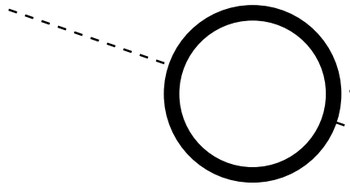

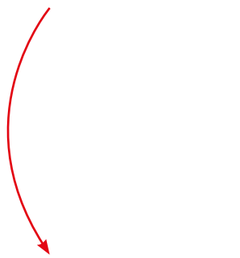

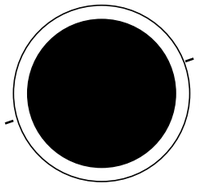

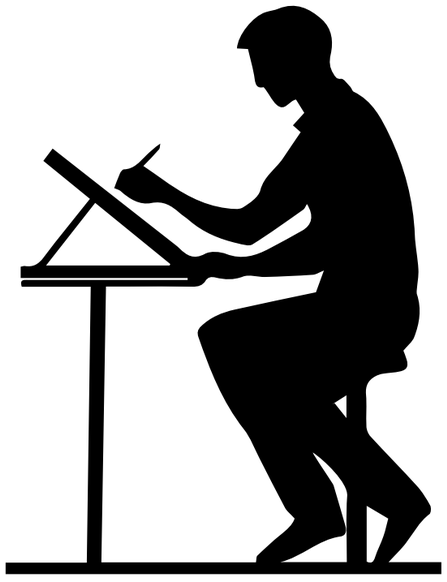

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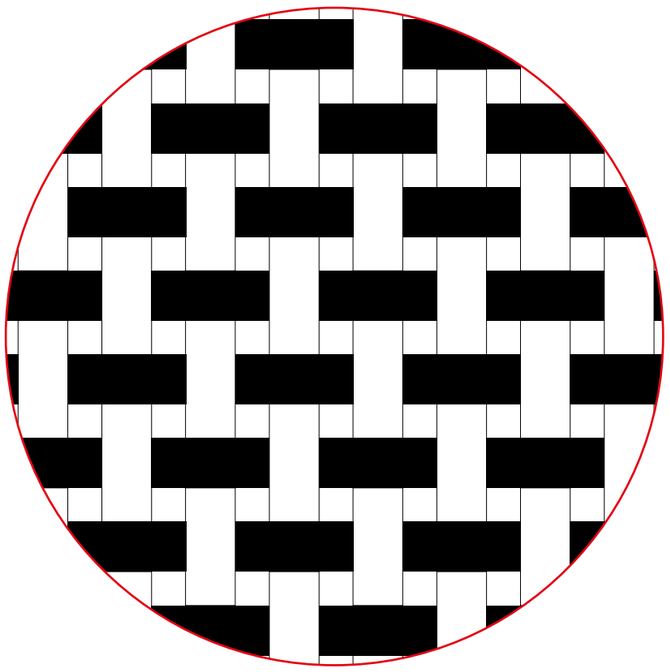

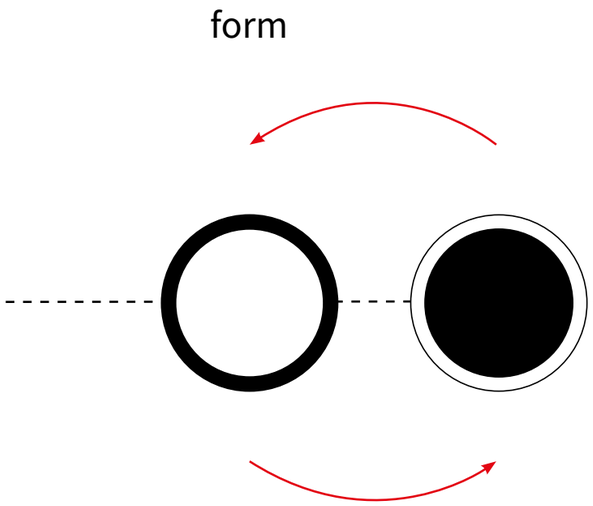

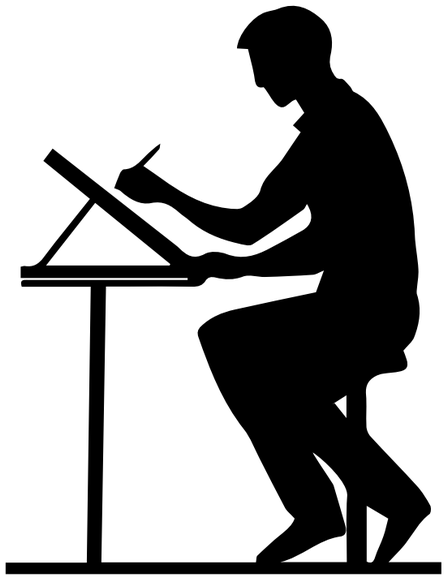

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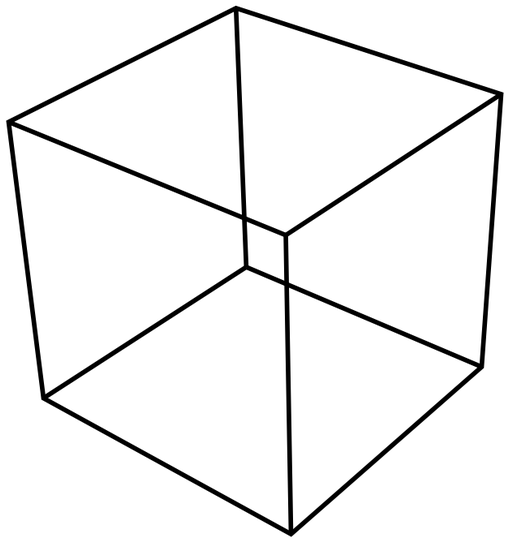

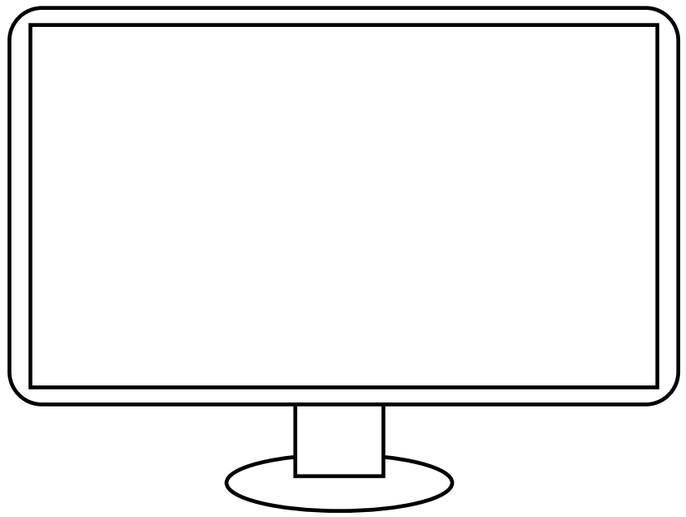

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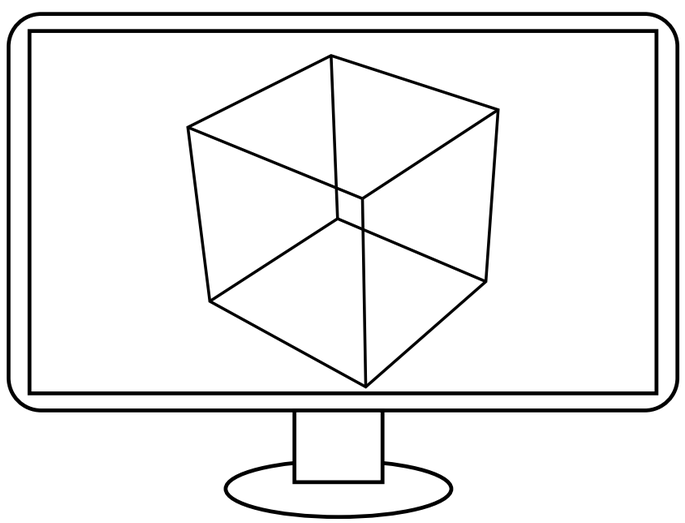

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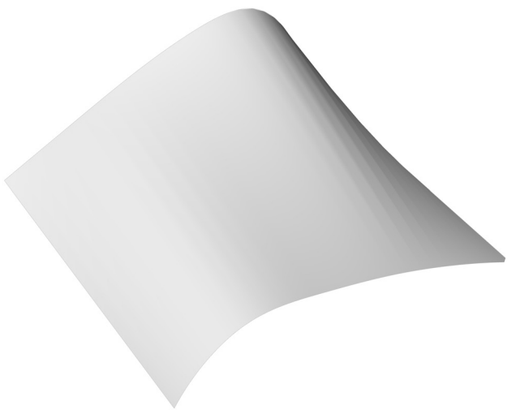

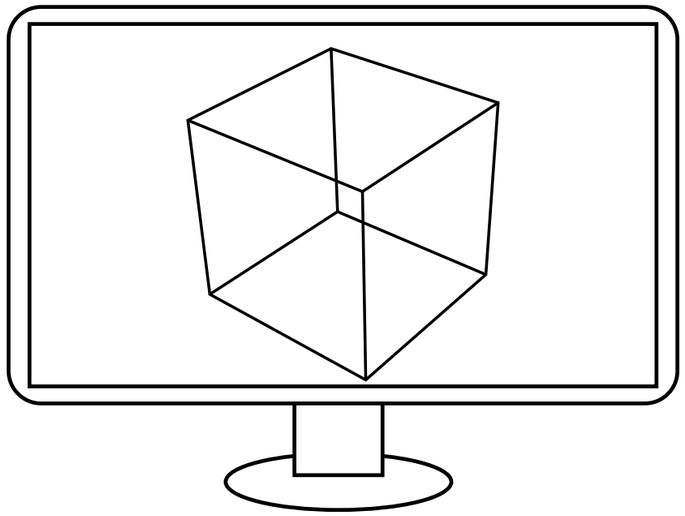

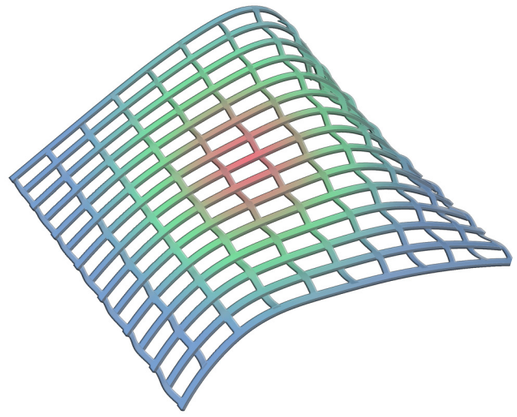

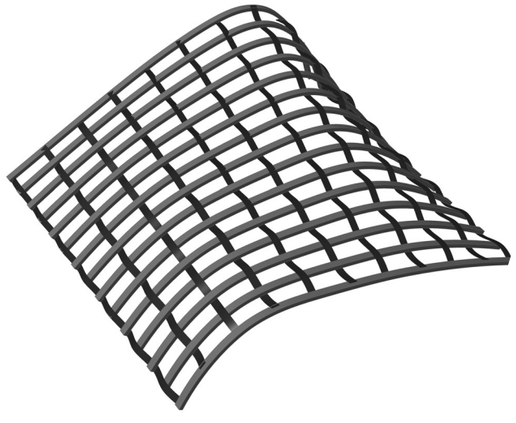

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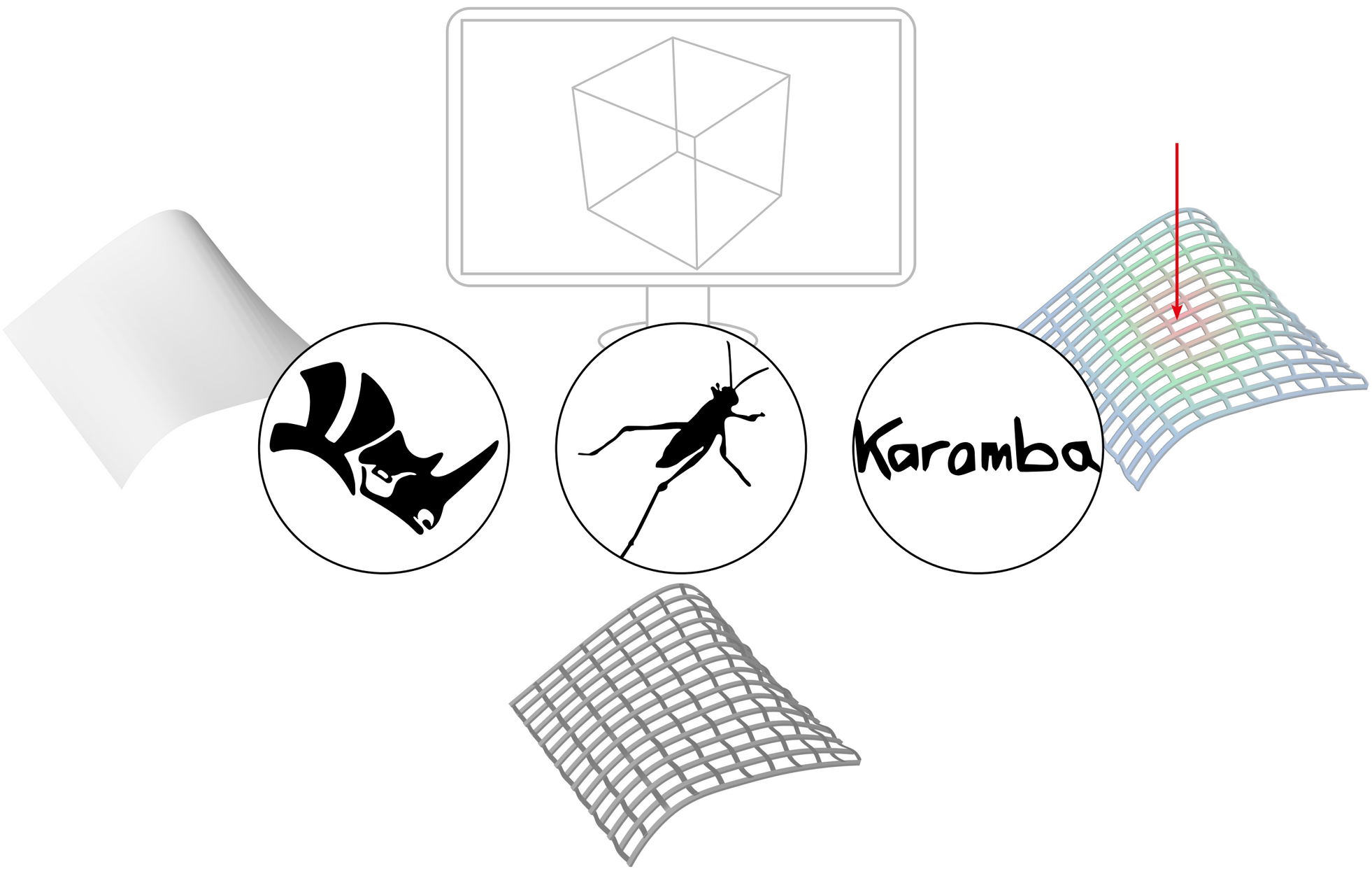


RESEARCH QUESTION

How can an architectural-scale woven structure be modelled and structurally analysed in a parametric setting?

RESEARCH QUESTION

How can an **architectural**-scale **woven** structure be **modelled** and **structurally analysed** in a **parametric** setting?

RESEARCH QUESTION

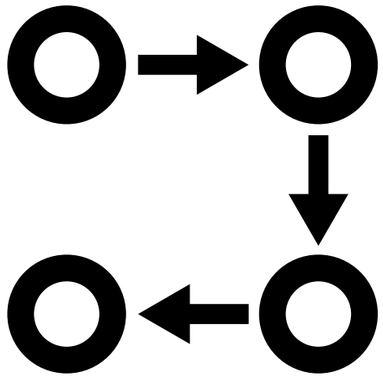
materiality

How can an **architectural**-scale **woven** structure be **modelled** and **structurally** **analysed** in a **parametric** setting?

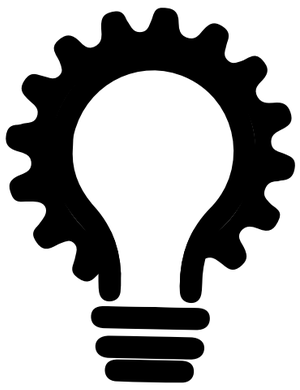
advantages & limitations

parameters

METHODOLOGY

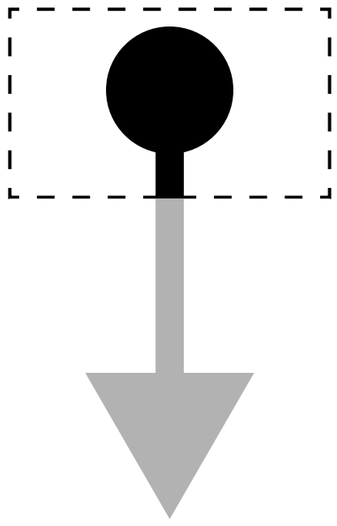


TOOL PROTOTYPE

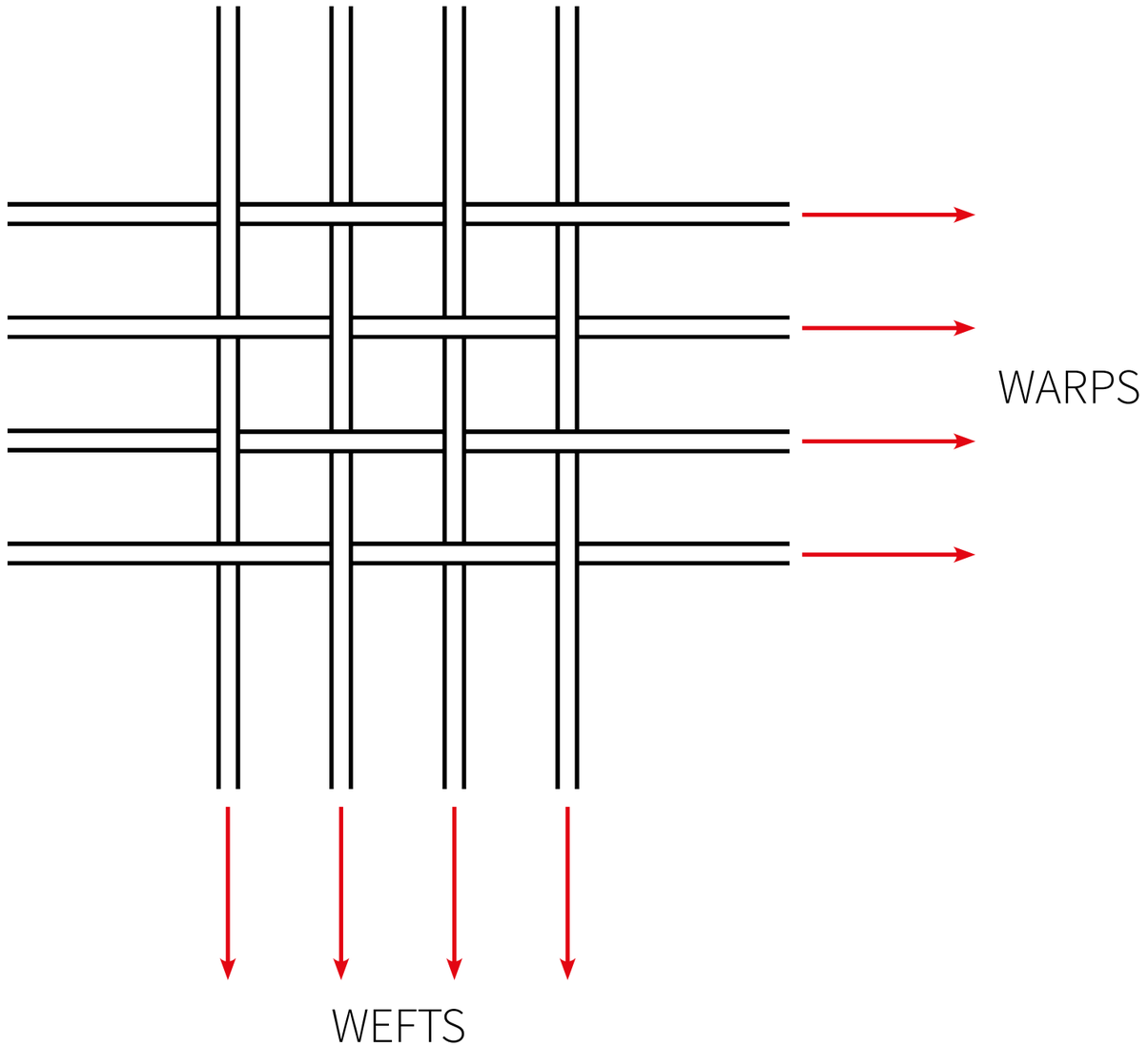


ARCHITECTS

EARLY DESIGN PHASE

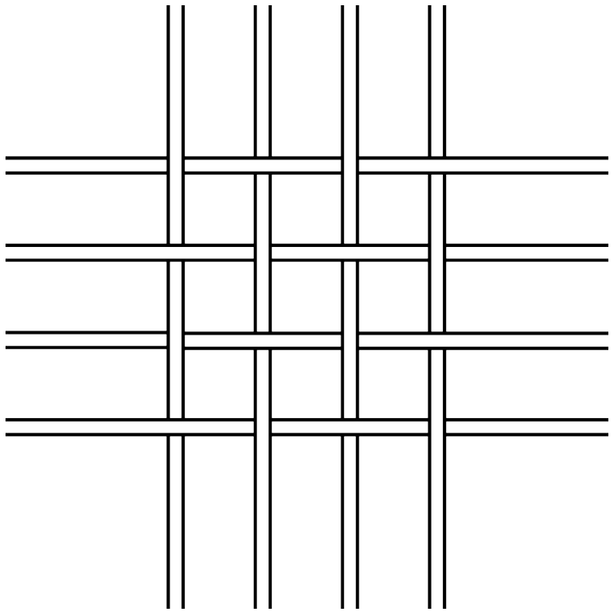


TERMINOLOGY & COMPONENTS

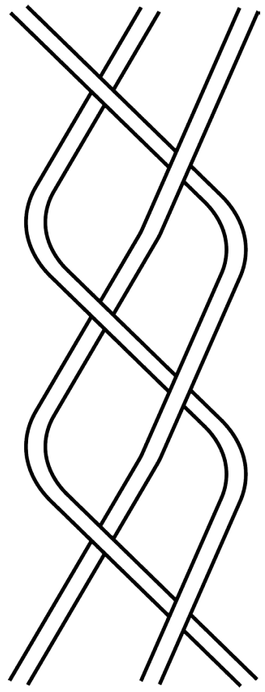


TERMINOLOGY & COMPONENTS

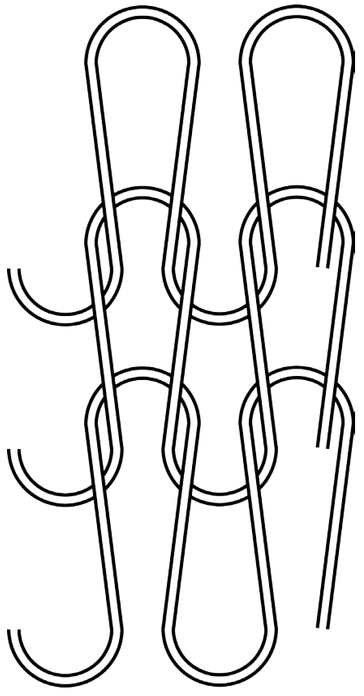
WEAVING



BRAIDING

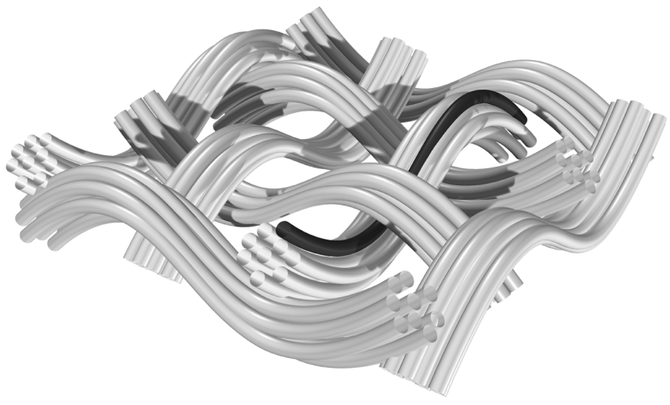


KNITTING

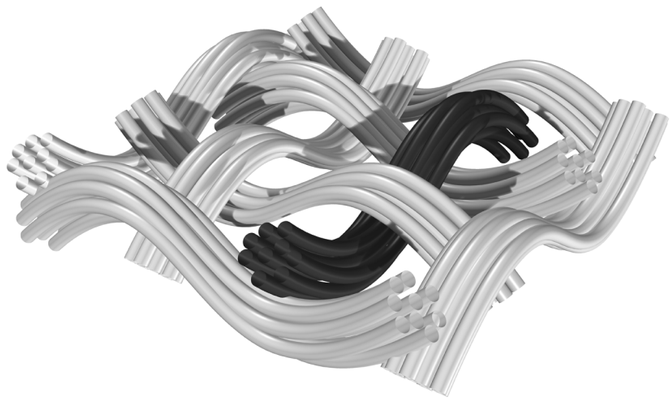


TERMINOLOGY & COMPONENTS

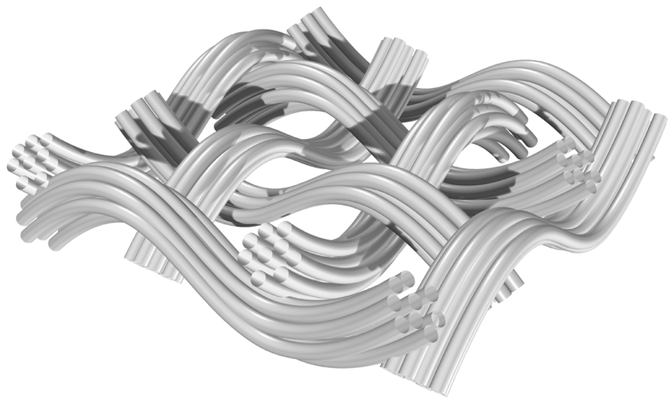
FIBRE



YARN



FABRIC



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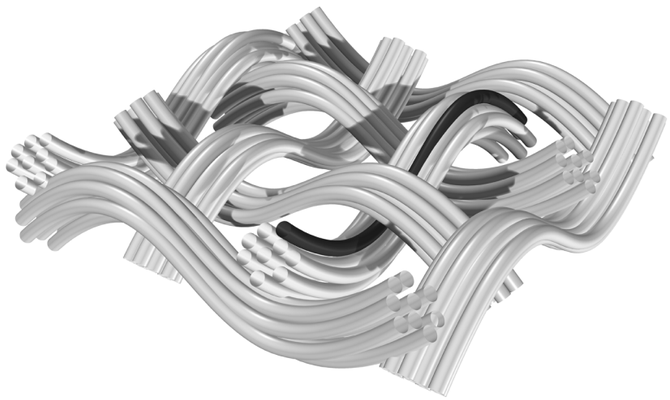
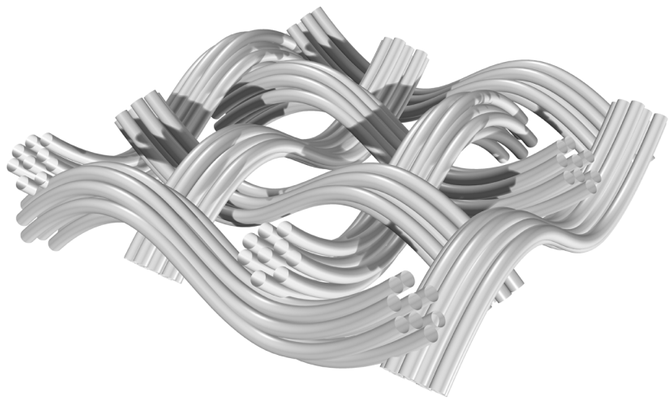


YARN

STRUCTURE



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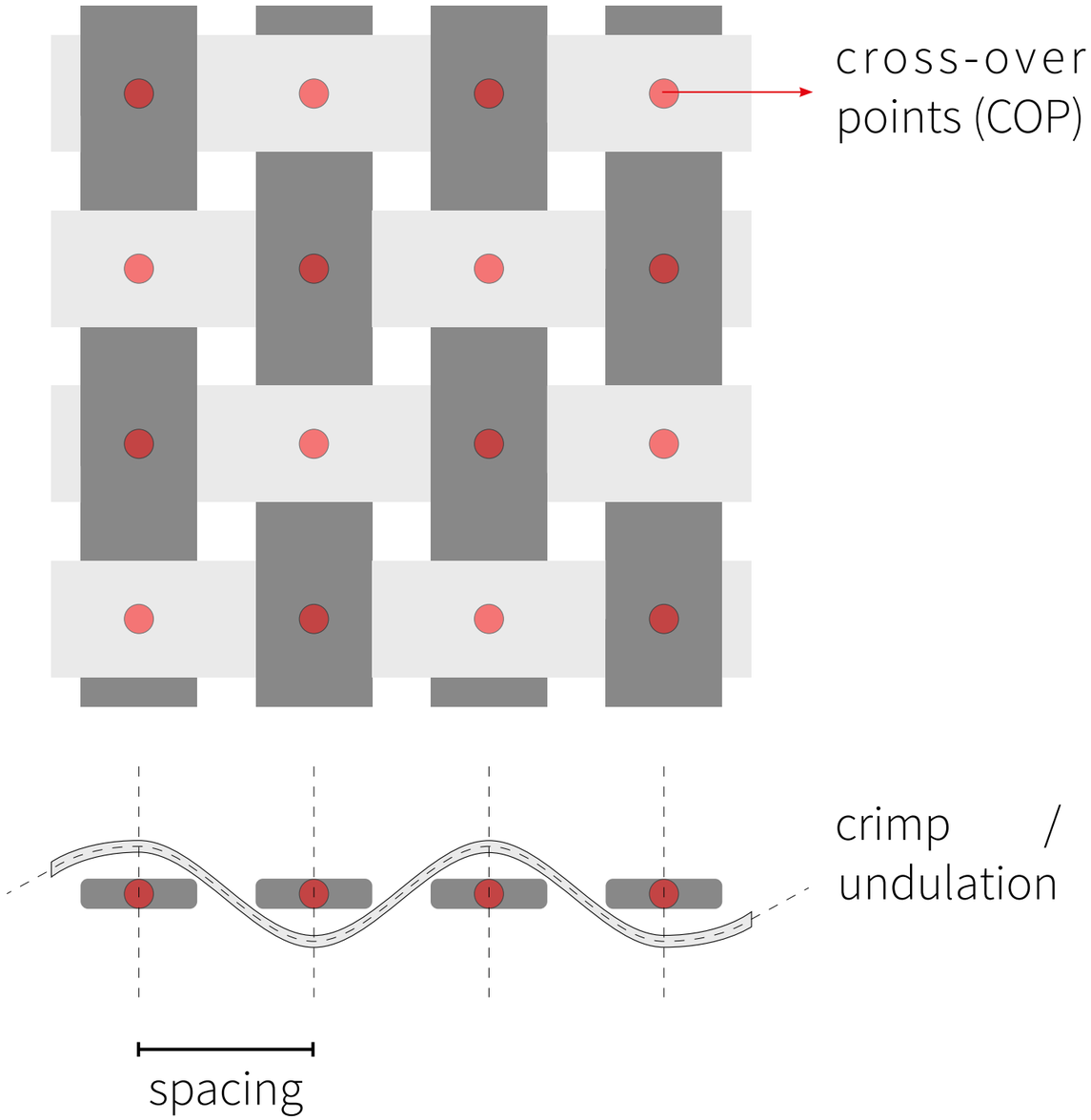

WEAVING IN ARCHITECTURE

Reconstruction of a vertical neolithic loom (Edal Anton Lefterov, 2008)

WEAVING IN ARCHITECTURE

Cadjan house in Myanmar (Michael Coghlan, 2013)

Dorze woven bamboo hut (Clarke, 2017)

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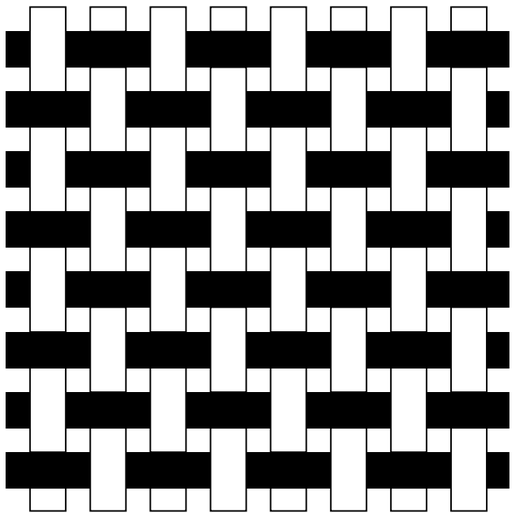
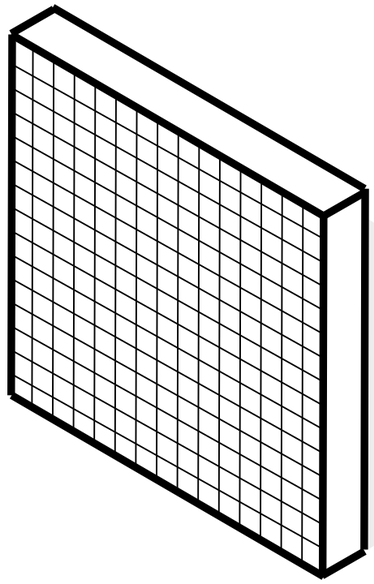
WEAVING IN ARCHITECTURE

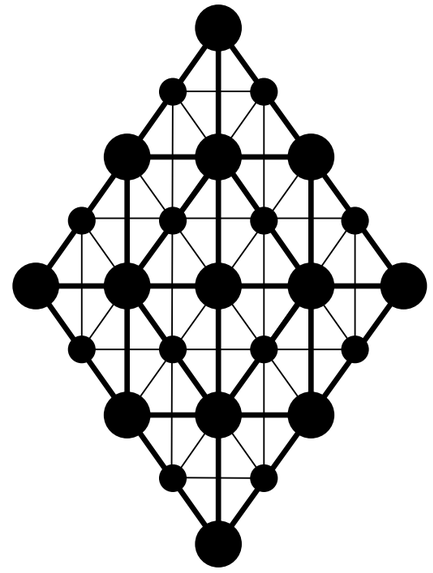
APPROACH 1



APPROACH 2



APPROACH 3

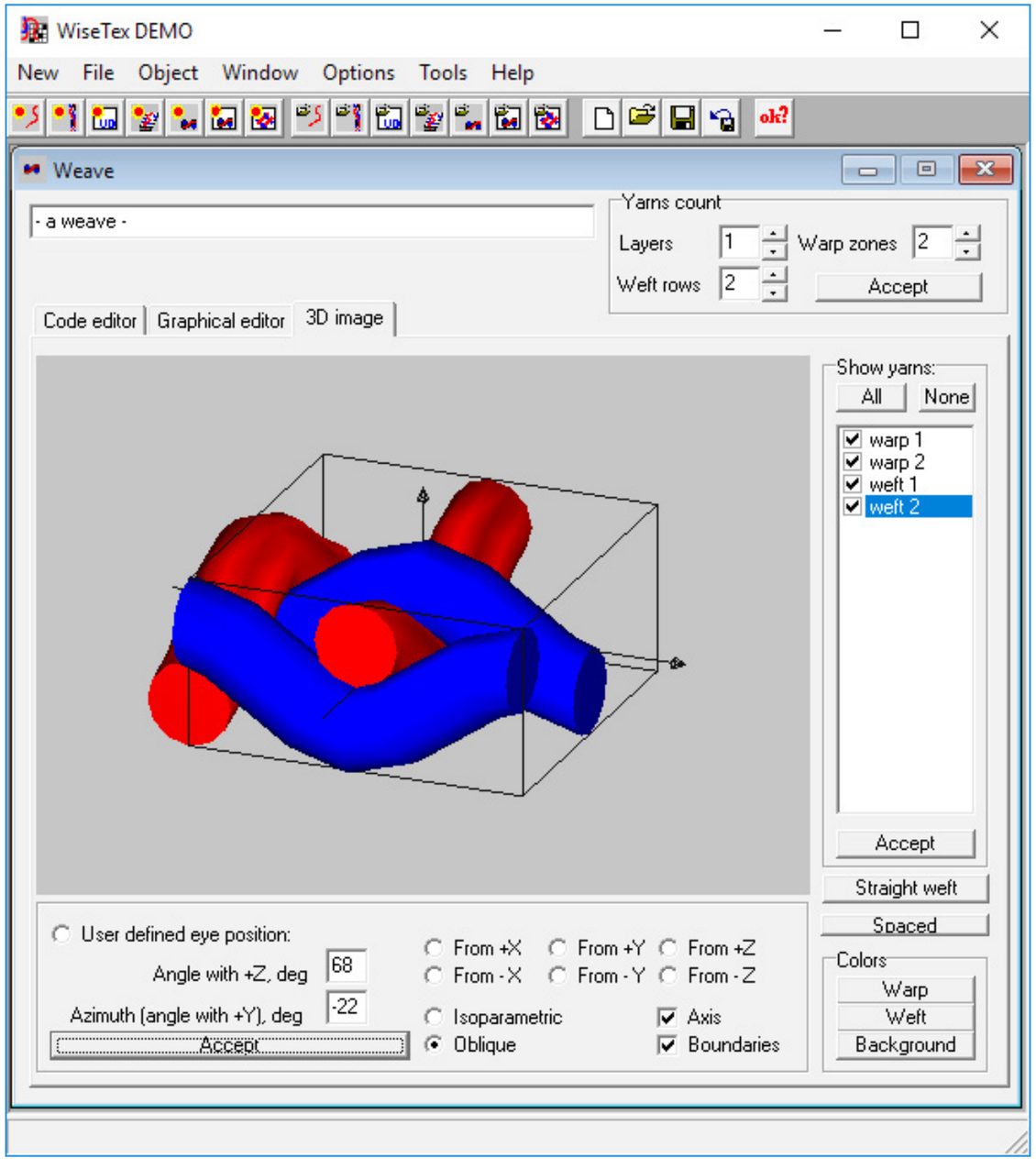


Weaving Enclosure (Naboni & Breseghello, 2016, fig. 19)

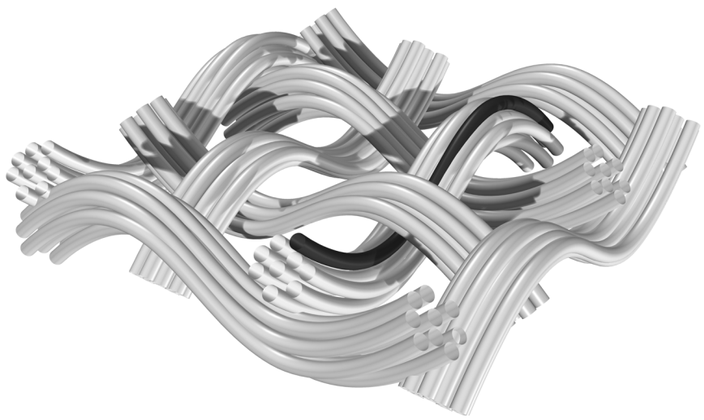
God's eye (Georgiou, Georgiou, & Williams, 2015, fig. 1)

Weaving project (Max Gerthel, n.d.)

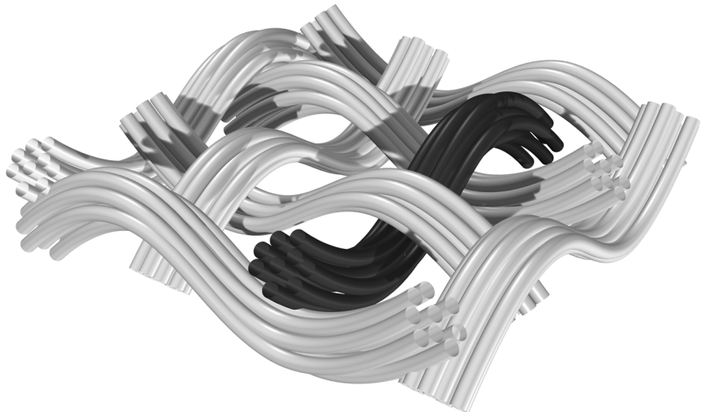
Spanish Pavilion Shanghai Expo 2010 (Halbe, 2010)


WiseTex DEMO
New File Object Window Options Tools Help
Weave
- a weave -
Yarns count
Layers 1
Warp zones 2
Weft rows 2
Accept
Code editor
Graphical editor
3D image
Show yarns:
All
None
warp 1
warp 2
weft 1
weft 2
Accept
Straight weft
Spaced
Colors
Warp
Weft
Background
User defined eye position:
Angle with +Z, deg 68
Azimuth (angle with +Y), deg -22
Accept
From +X
From +Y
From +Z
From -X
From -Y
From -Z
Isoparametric
Oblique
Axis
Boundaries

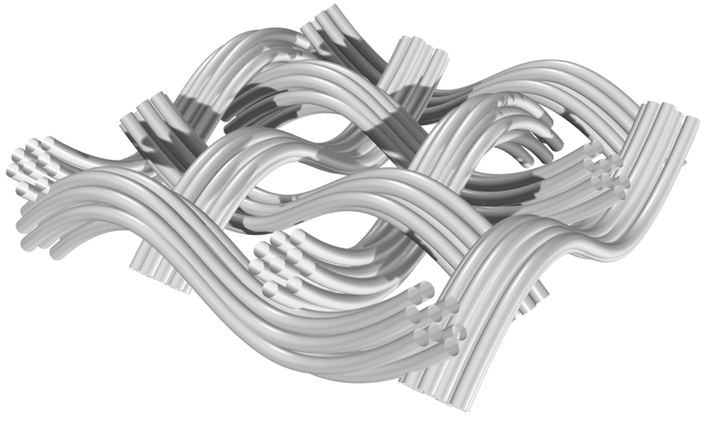
STRUCTURAL ANALYSIS



MICRO-MECHANICAL SCALE



MESO-MECHANICAL SCALE



MACRO-MECHANICAL SCALE

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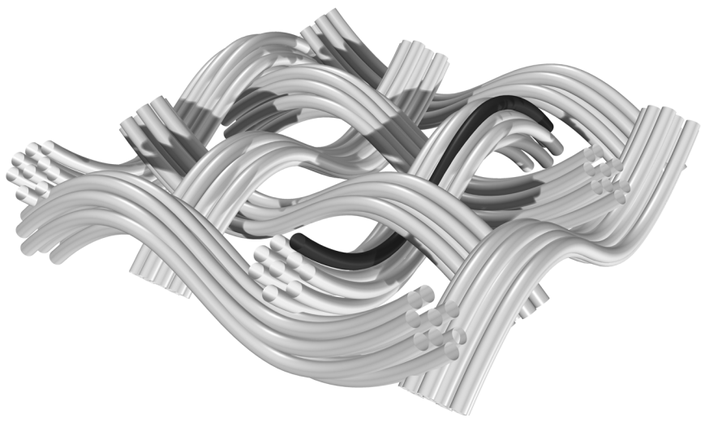
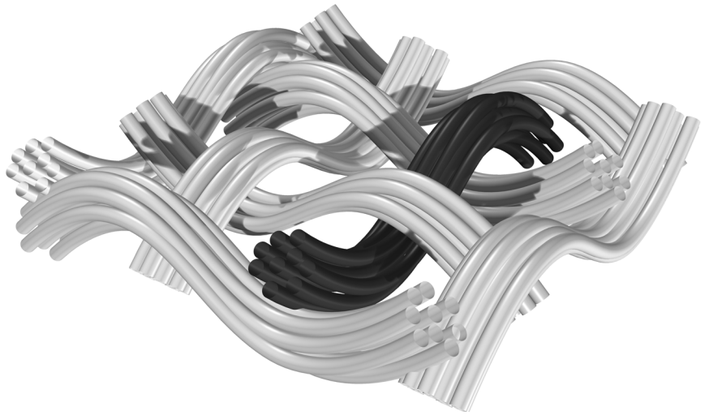
STRUCTURAL ANALYSIS



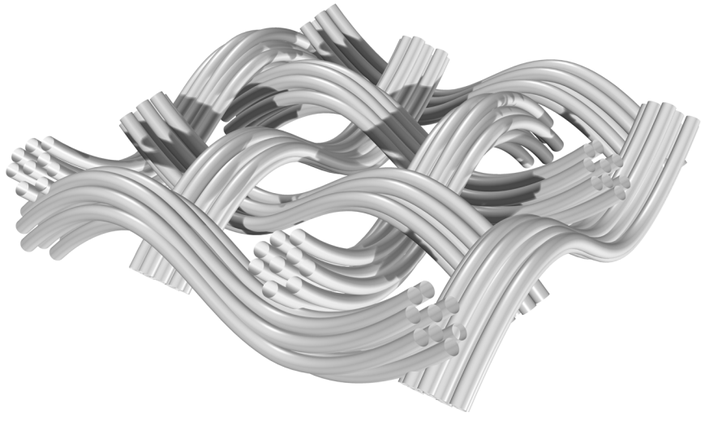
MICRO-MECHANICAL SCALE

microscopic response of fibres to
yarn deformation



MESO-MECHANICAL SCALE

cross-section
local displacement
friction
yarn path



MACRO-MECHANICAL SCALE

fabric as a whole
non-linear material behaviour

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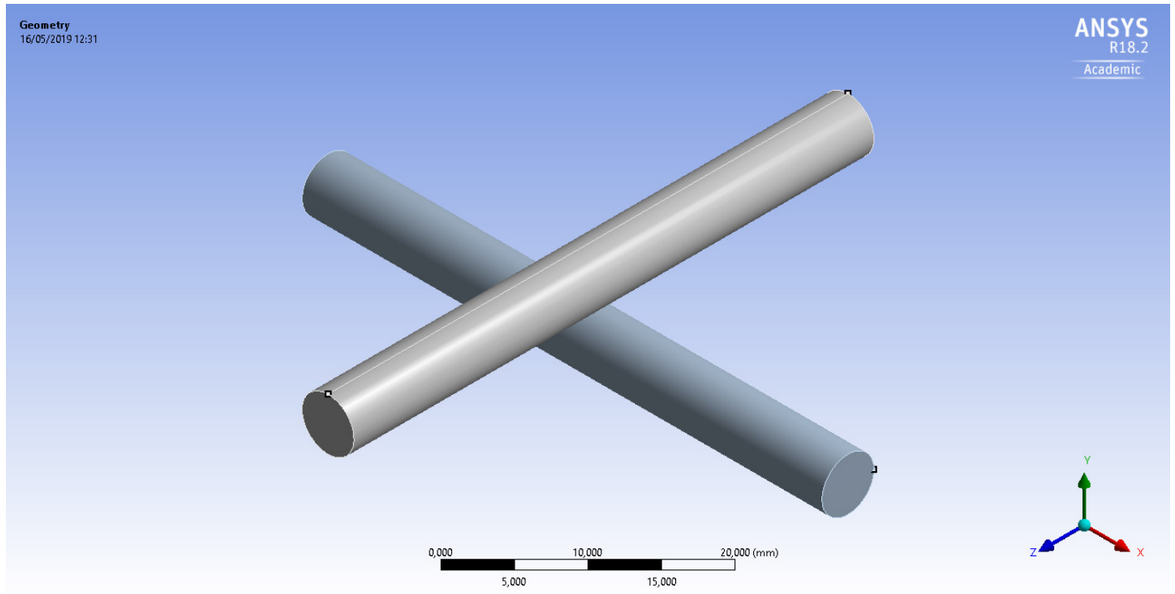
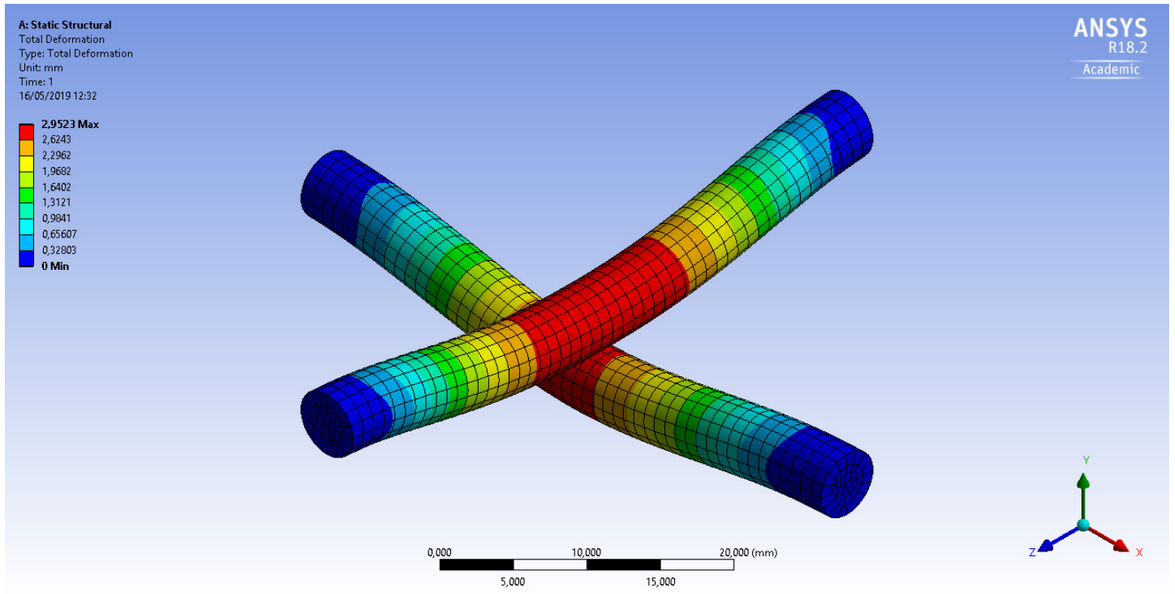
STRUCTURAL ANALYSIS





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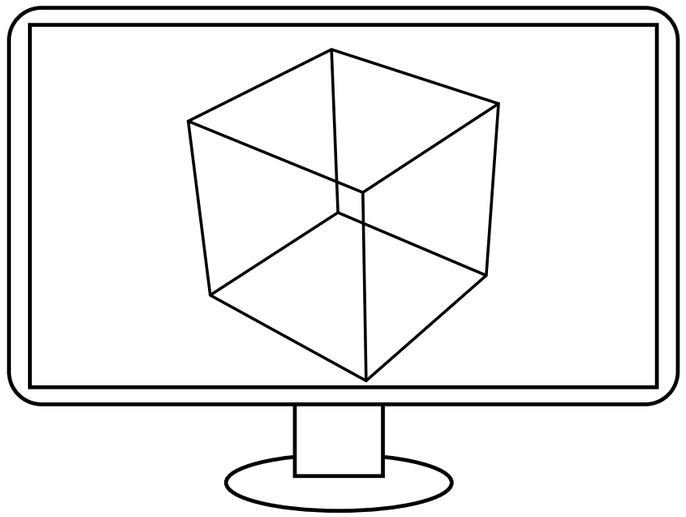
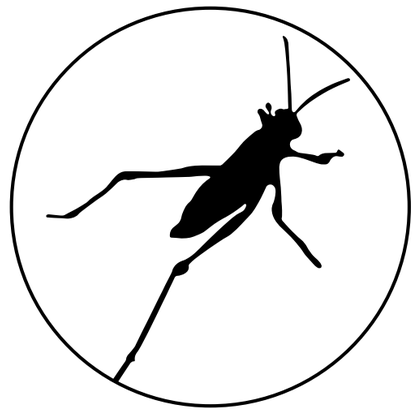
SPACEWEAVE





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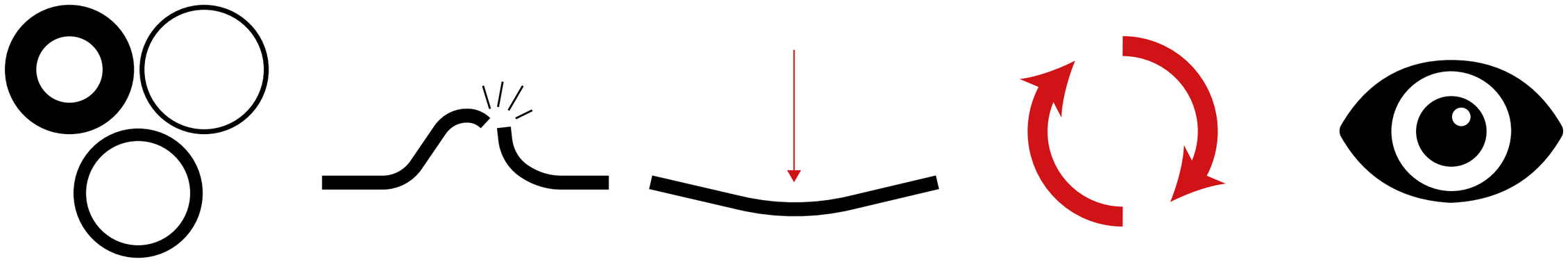
SPACEWEAVE: PURPOSE



DESIGN ALTERNATIVES

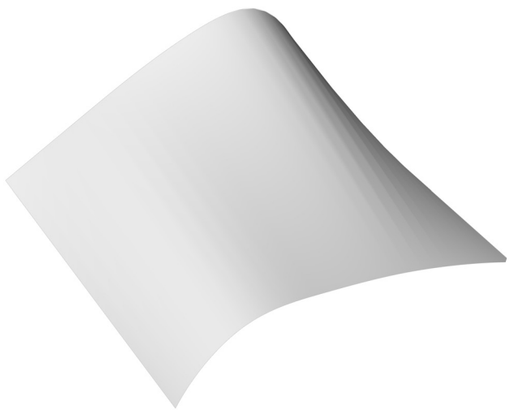
MATERIAL PROPERTIES

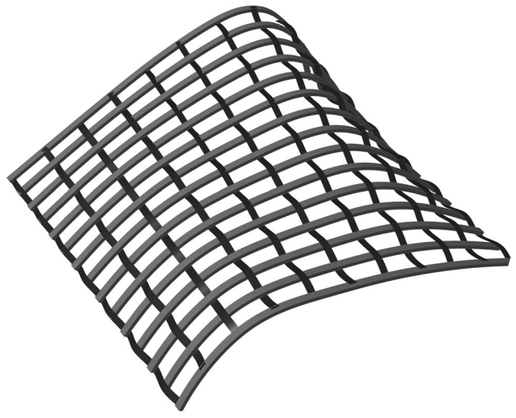
STRUCTURAL ANALYSIS

REGENERATION

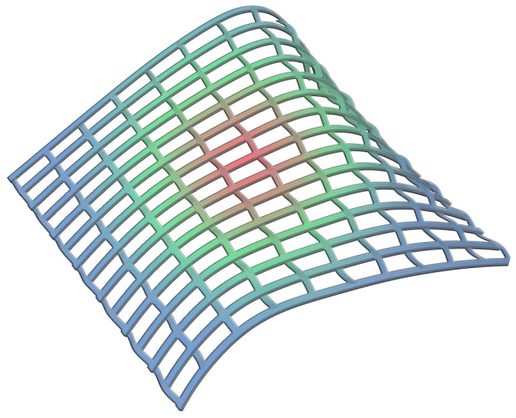
VISUALISATION

SPACEWEAVE: OVERVIEW



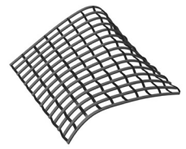


WEAVE MODELLING COMPONENT



STRUCTURAL ANALYSIS COMPONENT

WEAVE MODELLING: INPUTS



GEOMETRY

Surface

Pattern selection

Weft spacing

Warp spacing graphical definition

Warp spacing (fixed)

Warp count

Warp frequency curve

spacing inputs

MATERIALITY

Yield strength

Young's modulus

VIEW

View settings

Weft colour

Warp colour

Weft-warp switch

control input

Weft cross-section shape

Warp cross-section shape

Weft cross-section width

Warp cross-section width

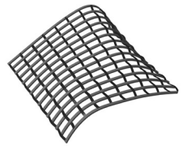
Weft cross-section height

Warp cross-section height

Weft cross-section radius

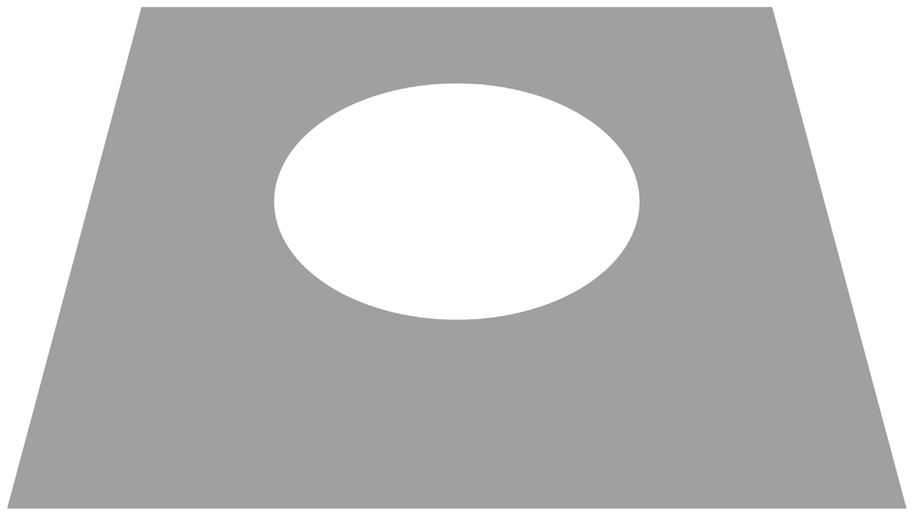
Warp cross-section radius

cross-section inputs

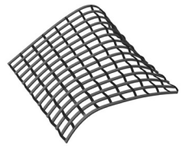


WEAVE MODELLING: GEOMETRY INPUTS

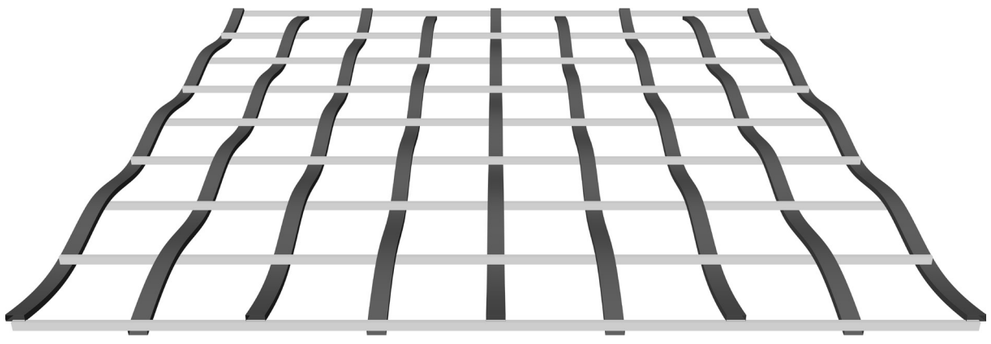
UNTRIMMED SURFACE



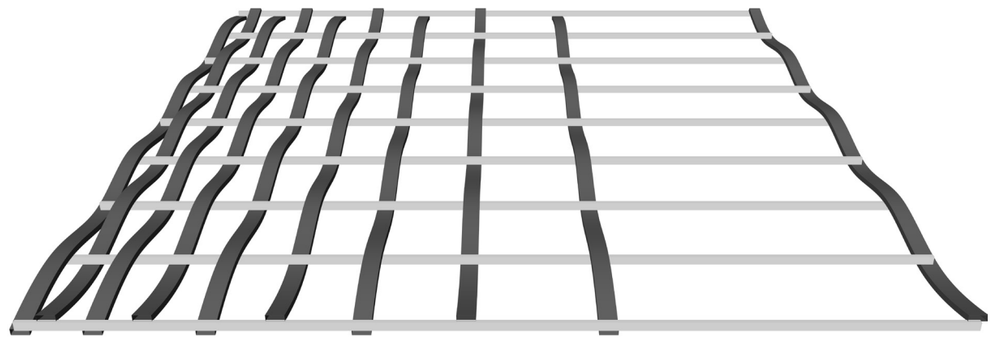
TRIMMED SURFACE



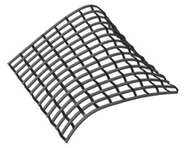
WEAVE MODELLING: GEOMETRY INPUTS



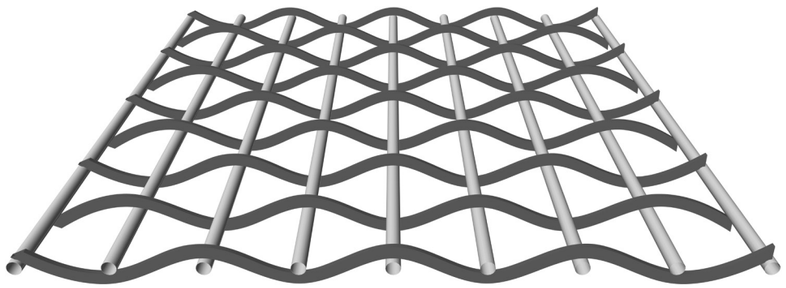
FIXED SPACING



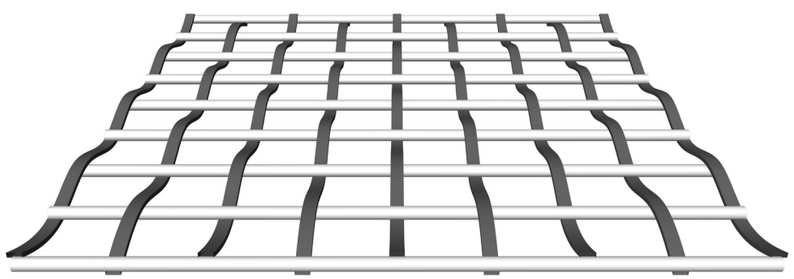
VARIABLE SPACING



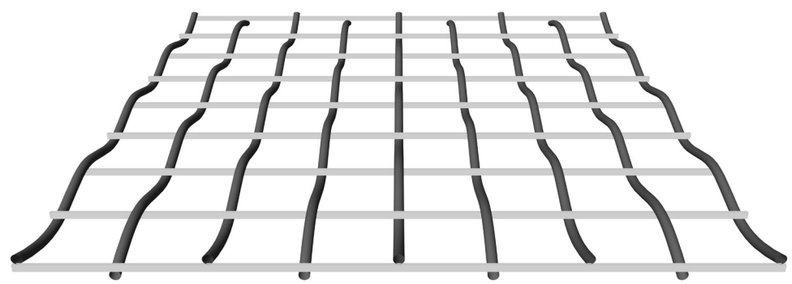
WEAVE MODELLING: GEOMETRY INPUTS



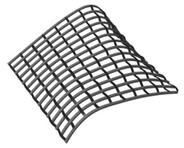
CIRCULAR CROSS-SECTION



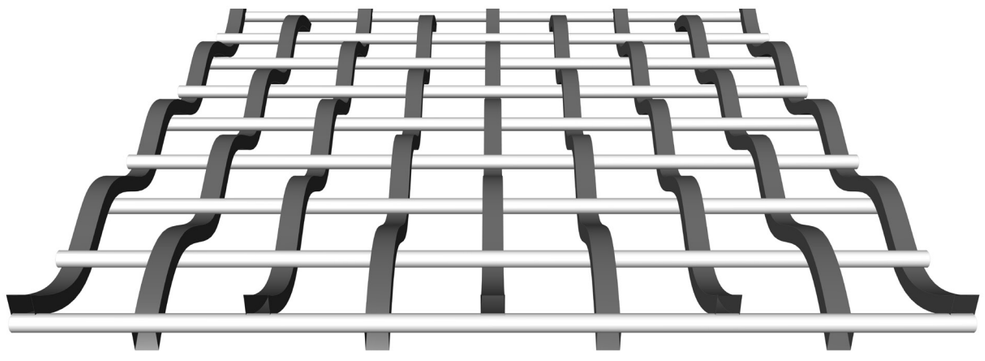
MIXED



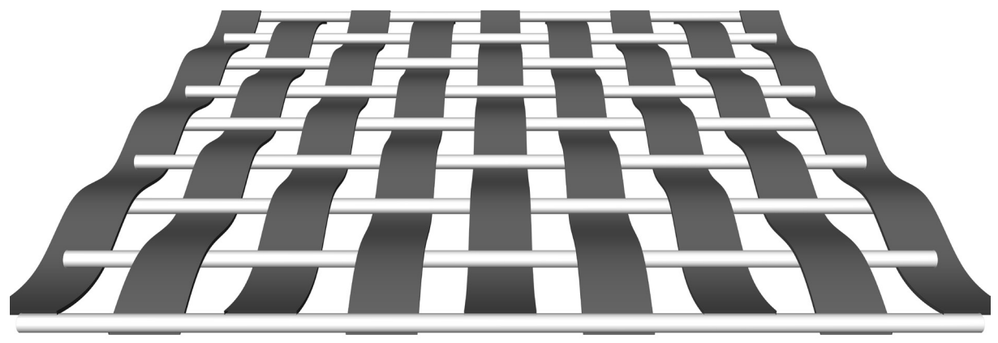
RECTANGULAR CROSS-SECTION



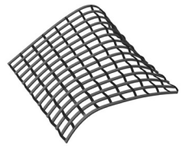
WEAVE MODELLING: GEOMETRY INPUTS



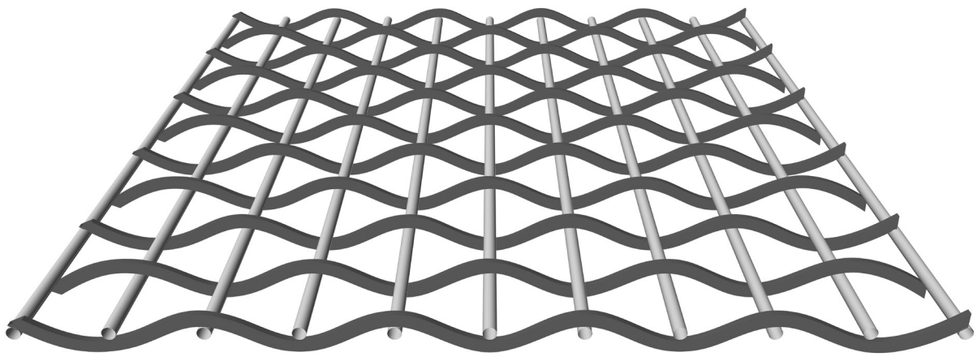
SMALLER WIDTH



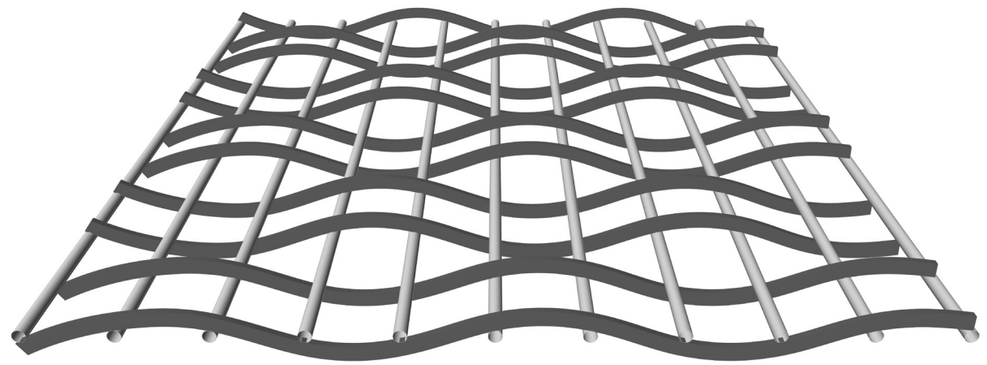
LARGER WIDTH



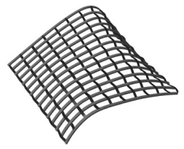
WEAVE MODELLING: GEOMETRY INPUTS



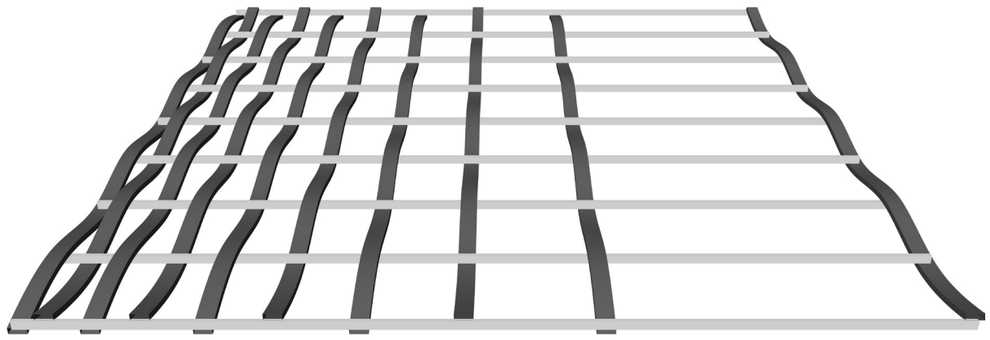
1-0 PATTERN (PLAIN)



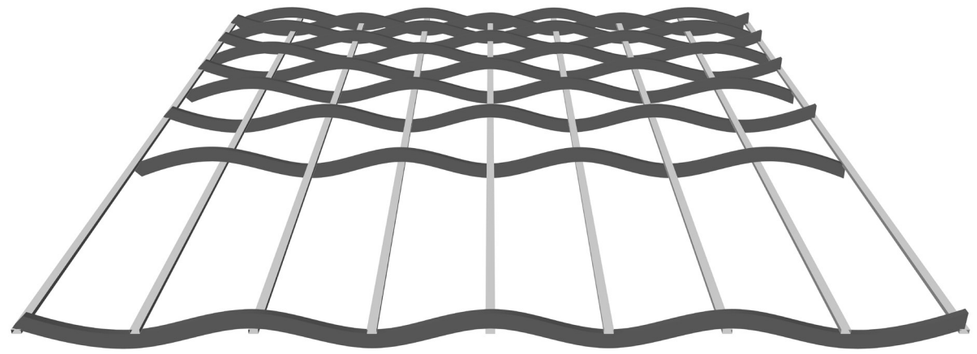
1-1-0-0 PATTERN (BASKET)



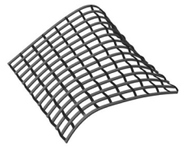
WEAVE MODELLING: GEOMETRY INPUTS



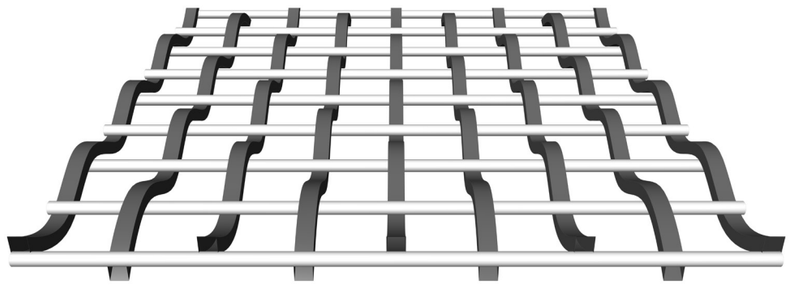
WARP-WEFT SWITCH: OFF



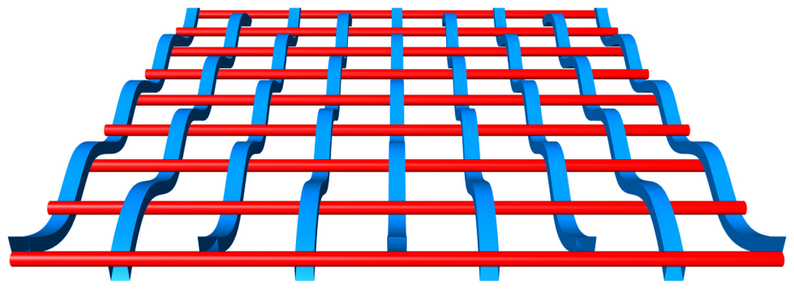
WARP-WEFT SWITCH: ON



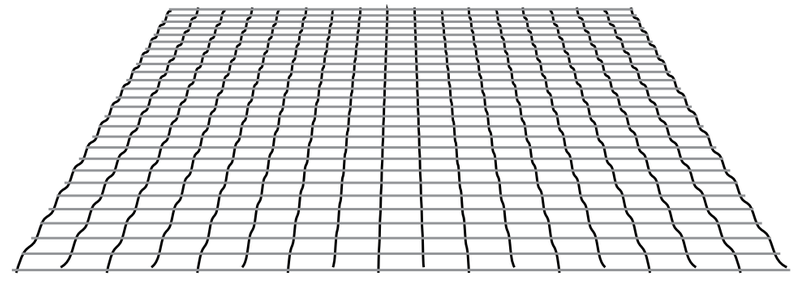
WEAVE MODELLING: VIEW INPUTS



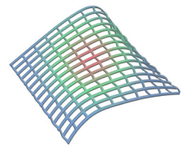
SHADED VIEW

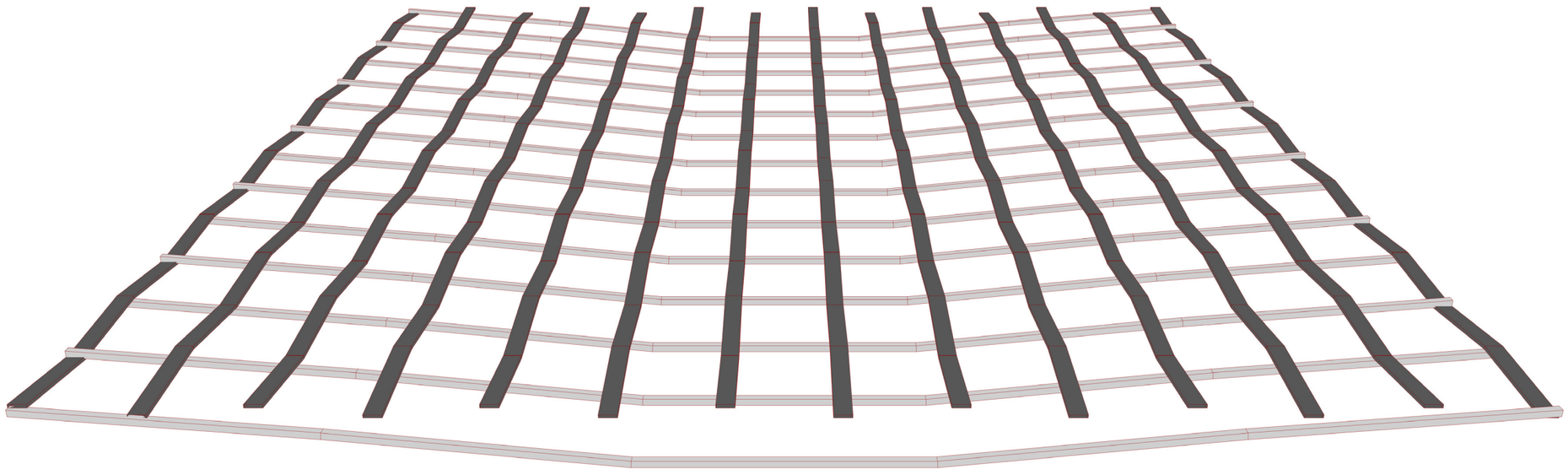


SHADED VIEW - COLOUR MANIPULATION

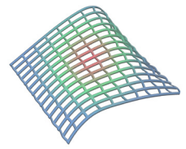


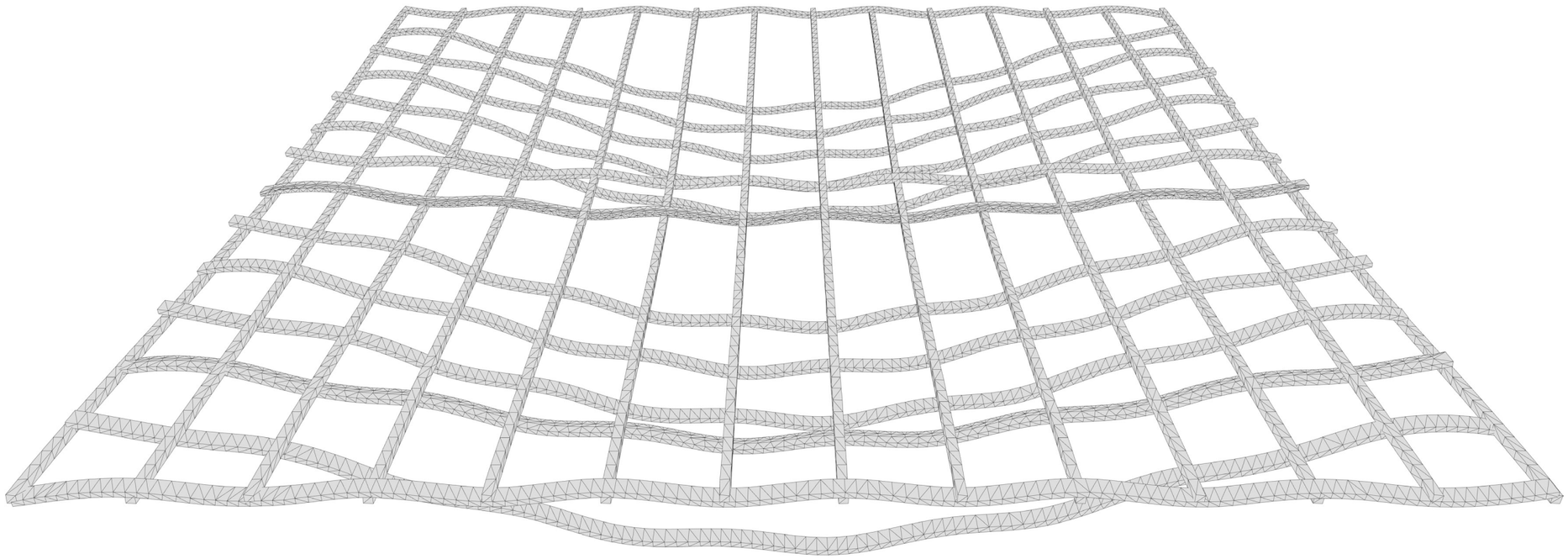
WIREFRAME VIEW



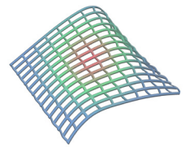


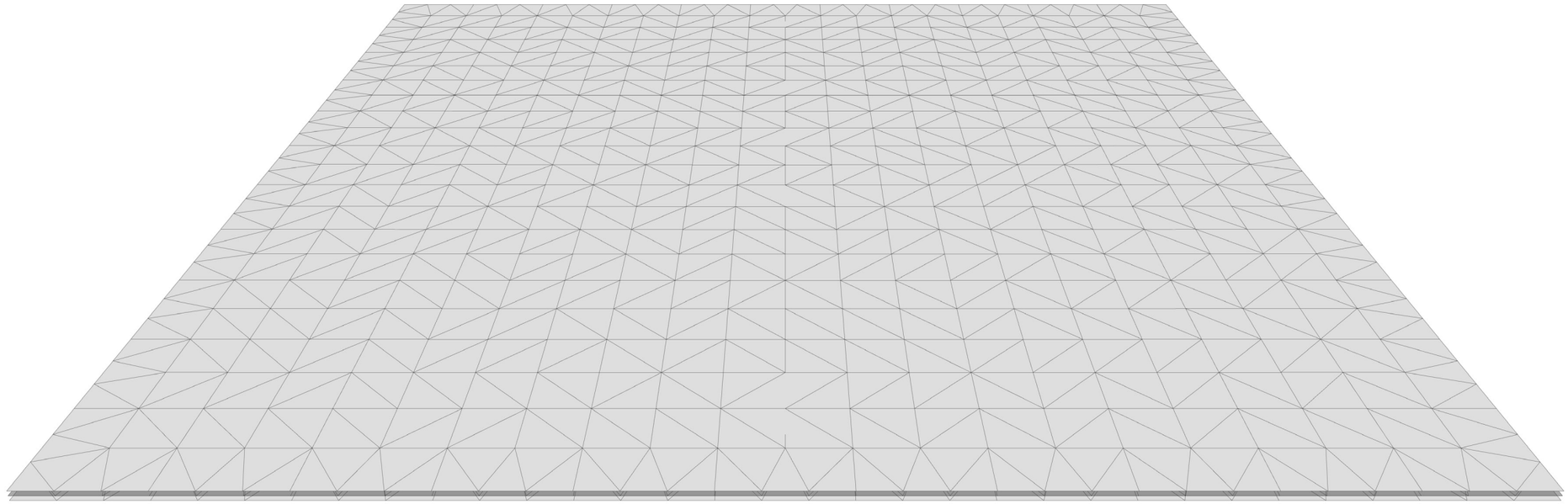
METHOD A



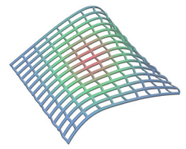


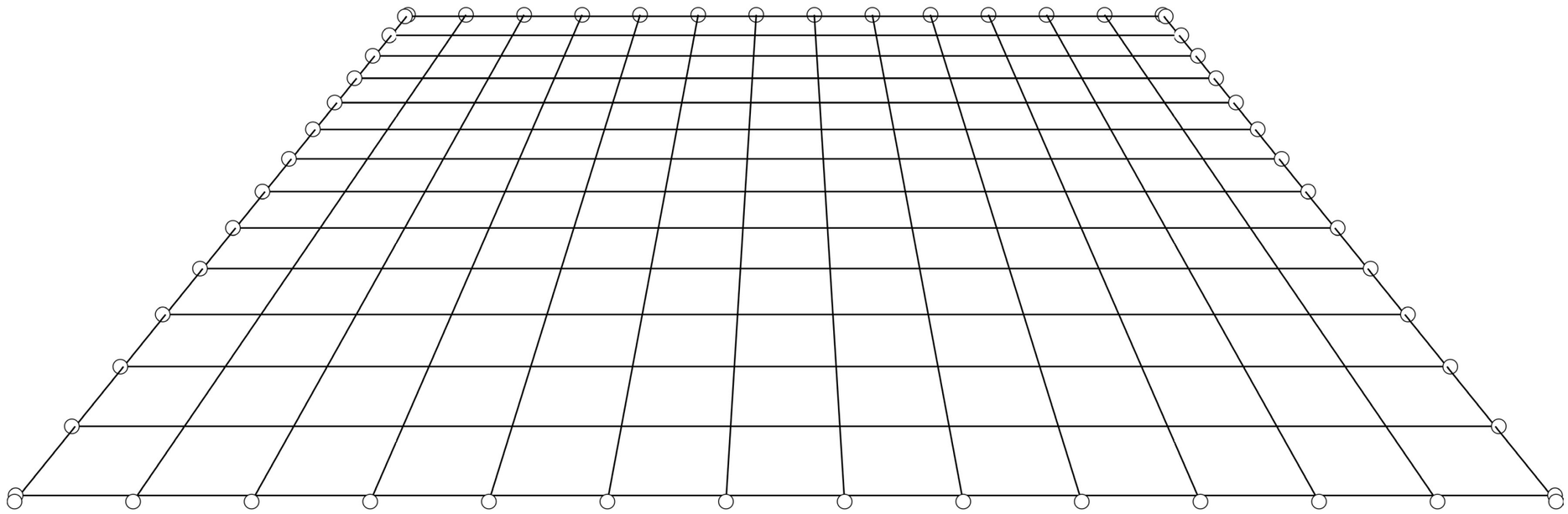
METHOD B



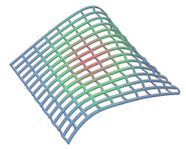


METHOD C





METHOD D



STRUCTURAL ANALYSIS: INPUTS

GEOMETRY

- Surface
- Wefts
- Warps

cross-section inputs:
- Weft cross-section shape
- Warp cross-section shape
- Weft cross-section width
- Warp cross-section width
- Weft cross-section height
- Warp cross-section height
- Weft cross-section radius
- Warp cross-section radius

control input:
- Warp-Weft switch

spacing inputs:
- Weft spacing
- Warp spacing

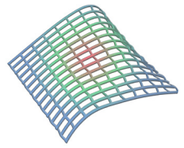
MATERIALITY

- Material name
- Young's modulus (GPa)
- Specific weight (kg/m^3)
- Poisson's ratio

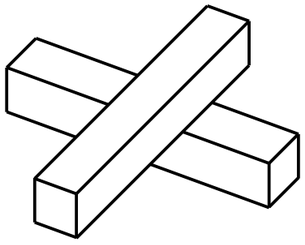
LOADS

- Interior - Exterior selection
- Location selection
- Wind vector definition
- Cover switch

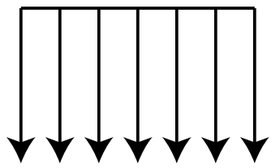
Estimated cover load



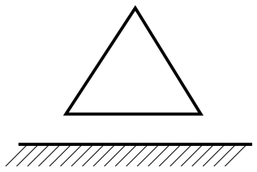
STRUCTURAL ANALYSIS: COMPONENTS



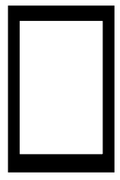
ELEMENTS



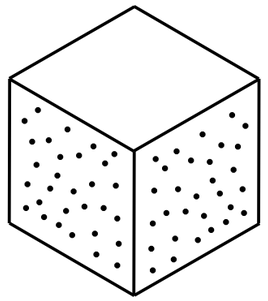
LOADS



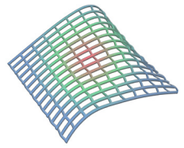
SUPPORTS



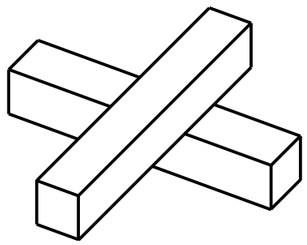
CROSS-SECTIONS



MATERIAL



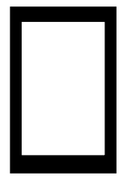
STRUCTURAL ANALYSIS: BEAMS & CROSS-SECTIONS



ELEMENTS

LOADS

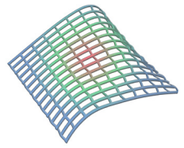
SUPPORTS



CROSS-SECTIONS

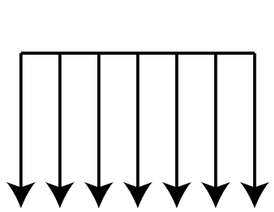
MATERIAL

1 2 3 4 5



STRUCTURAL ANALYSIS: LOADS

ELEMENTS

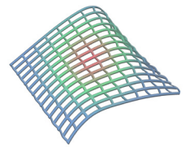


LOADS

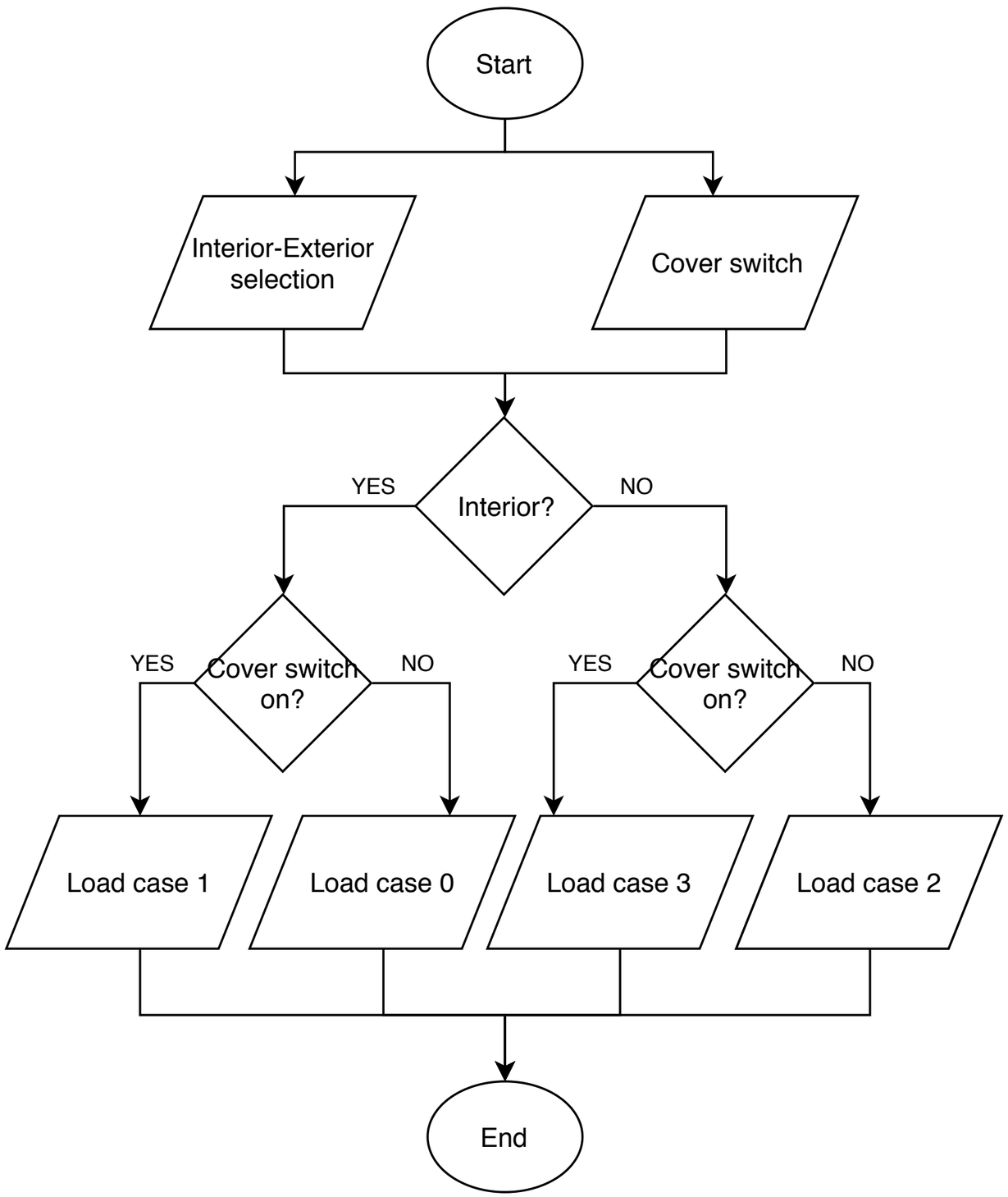
SUPPORTS

CROSS-SECTIONS

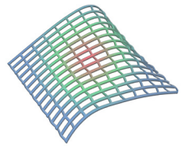
MATERIAL



STRUCTURAL ANALYSIS: LOADCASES



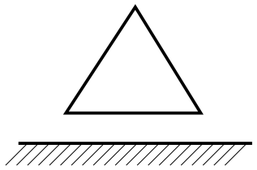
1 2 3 4 5



STRUCTURAL ANALYSIS: SUPPORTS

ELEMENTS

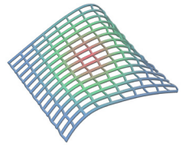
LOADS



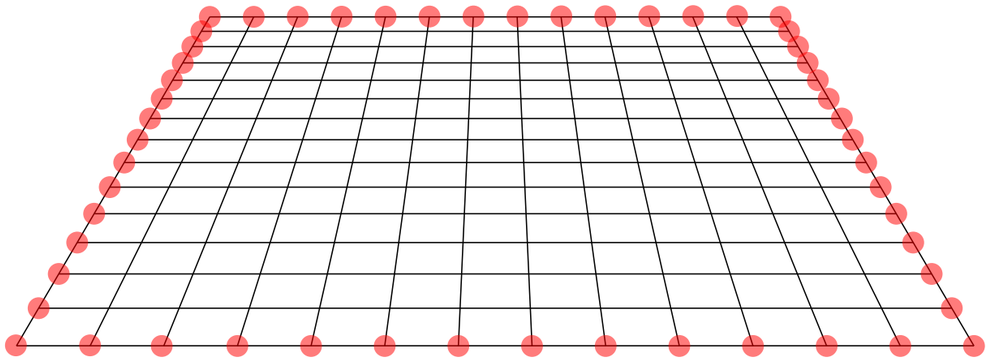
SUPPORTS

CROSS-SECTIONS

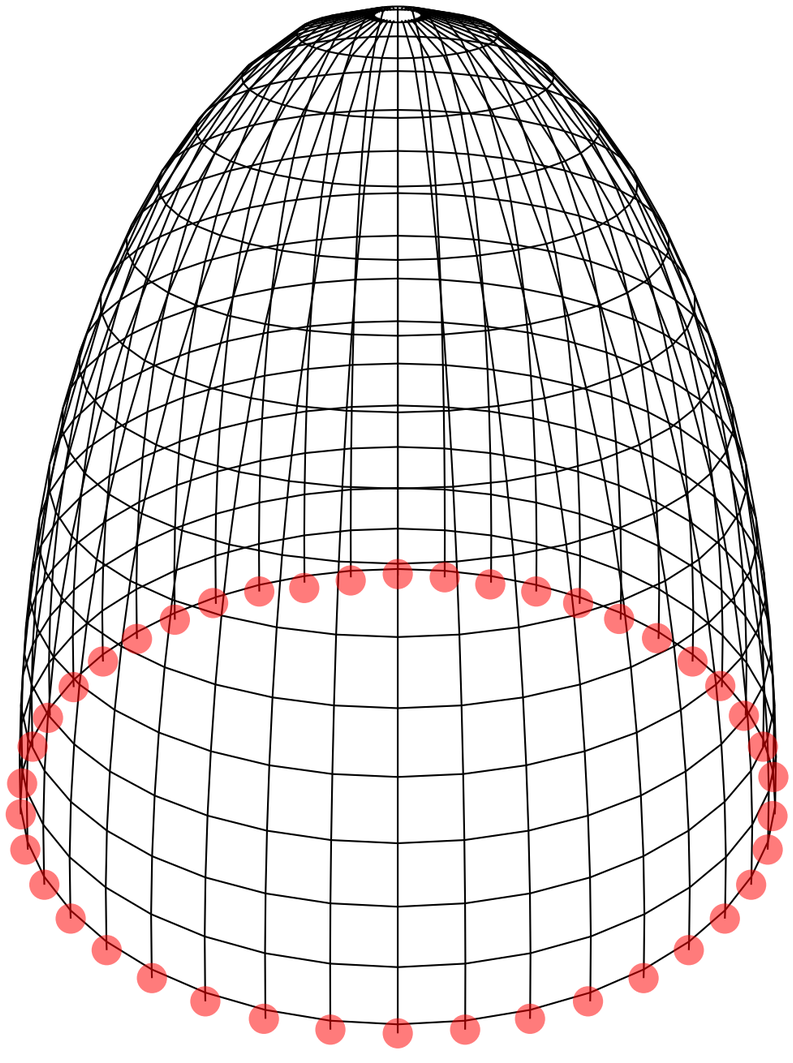
MATERIAL



STRUCTURAL ANALYSIS: SUPPORTS

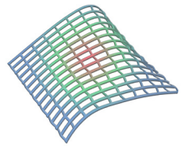


PLANAR SURFACE SUPPORTS



NON-PLANAR SURFACE SUPPORTS

1 2 3 4 5



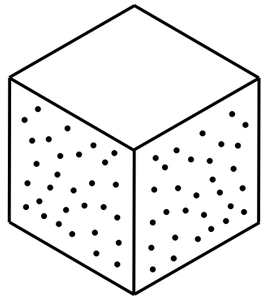
STRUCTURAL ANALYSIS: MATERIAL

ELEMENTS

LOADS

SUPPORTS

CROSS-SECTIONS



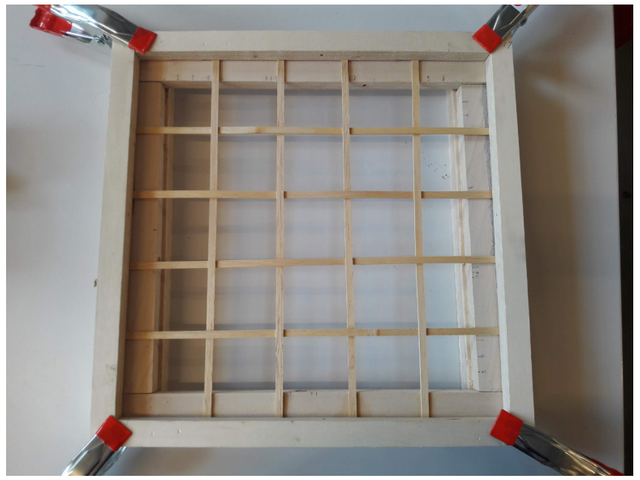
MATERIAL

STRUCTURAL ANALYSIS: PHYSICAL TESTING

WOVEN TEST UNIT

TEST UNIT LOADING

STRUCTURAL ANALYSIS: PHYSICAL TESTING



Load (kN)	Displacement (m)		Difference (m)	Karamba/Physical test value ratio
	AVERAGE 6-FIBRE	KARAMBA 6-FIBRE		
0,000	0,000	0,000	0,000	
0,010	0,006	0,005	-0,001	0,823
0,020	0,011	0,010	-0,001	0,939
0,029	0,015	0,015	0,000	1,021

Load (kN)	Displacement (m)		Difference (m)	Karamba/Physical test value ratio
	AVERAGE 4-FIBRE	KARAMBA 4-FIBRE		
0,000	0,000	0,000	0,000	
0,010	0,010	0,006	-0,004	0,616
0,020	0,016	0,012	-0,003	0,794
0,029	0,021	0,018	-0,003	0,876

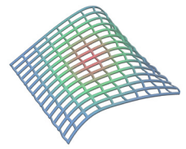
Difference between physical test and Karamba simulation results

STRUCTURAL ANALYSIS: EVALUATION

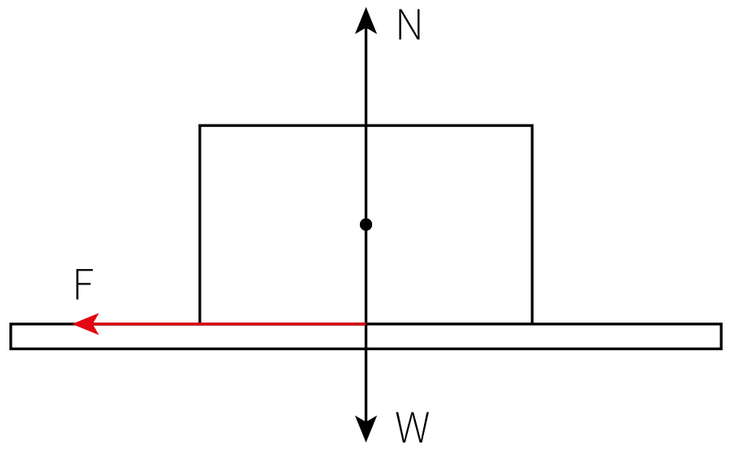
Load (kN)	Displacement (m)		Difference (m)	Karamba/Physical test value ratio
	AVERAGE 6-FIBRE	KARAMBA 6-FIBRE		
0,000	0,000	0,000	0,000	
0,010	0,006	0,005	-0,001	0,823
0,020	0,011	0,010	-0,001	0,939
0,029	0,015	0,015	0,000	1,021

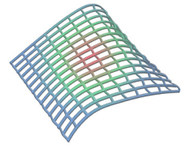
Load (kN)	Displacement (m)		Difference (m)	Karamba/Physical test value ratio
	AVERAGE 4-FIBRE	KARAMBA 4-FIBRE		
0,000	0,000	0,000	0,000	
0,010	0,010	0,006	-0,004	0,616
0,020	0,016	0,012	-0,003	0,794
0,029	0,021	0,018	-0,003	0,876

Difference between physical test and Karamba simulation results

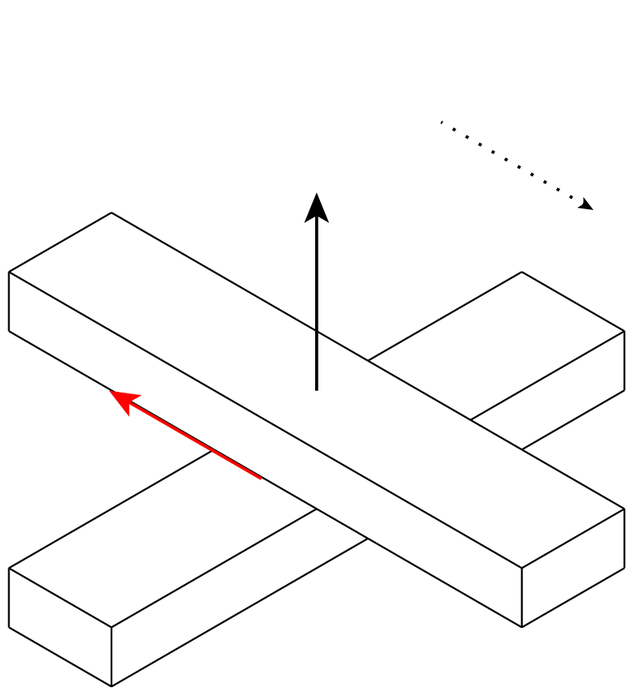


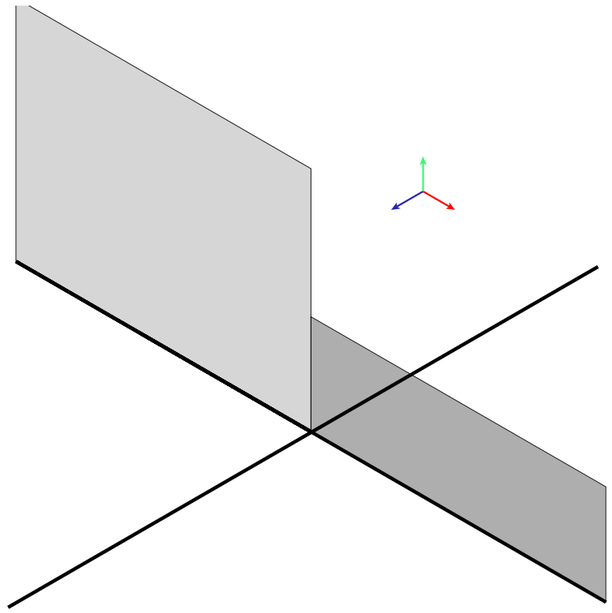
STRUCTURAL ANALYSIS: FRICTION

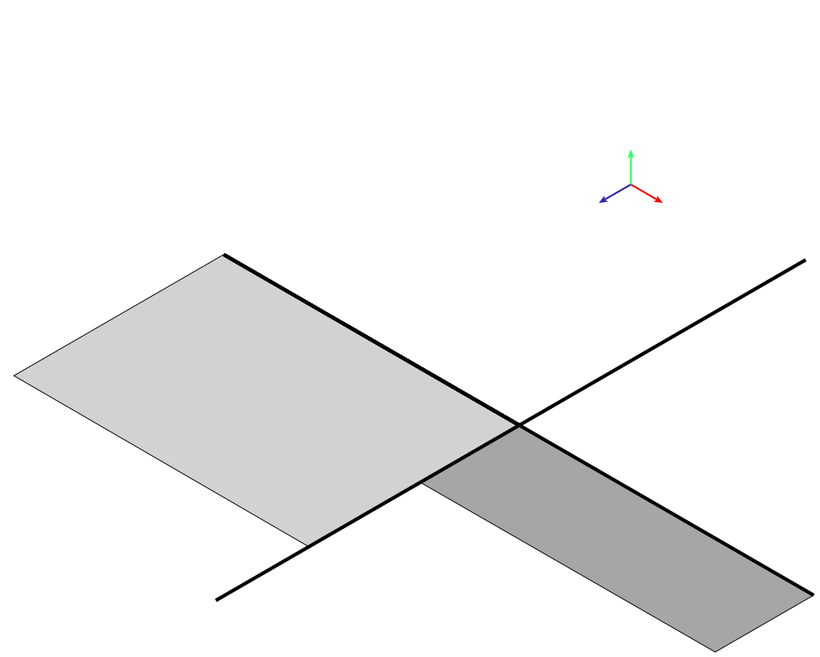




STRUCTURAL ANALYSIS: FRICTION

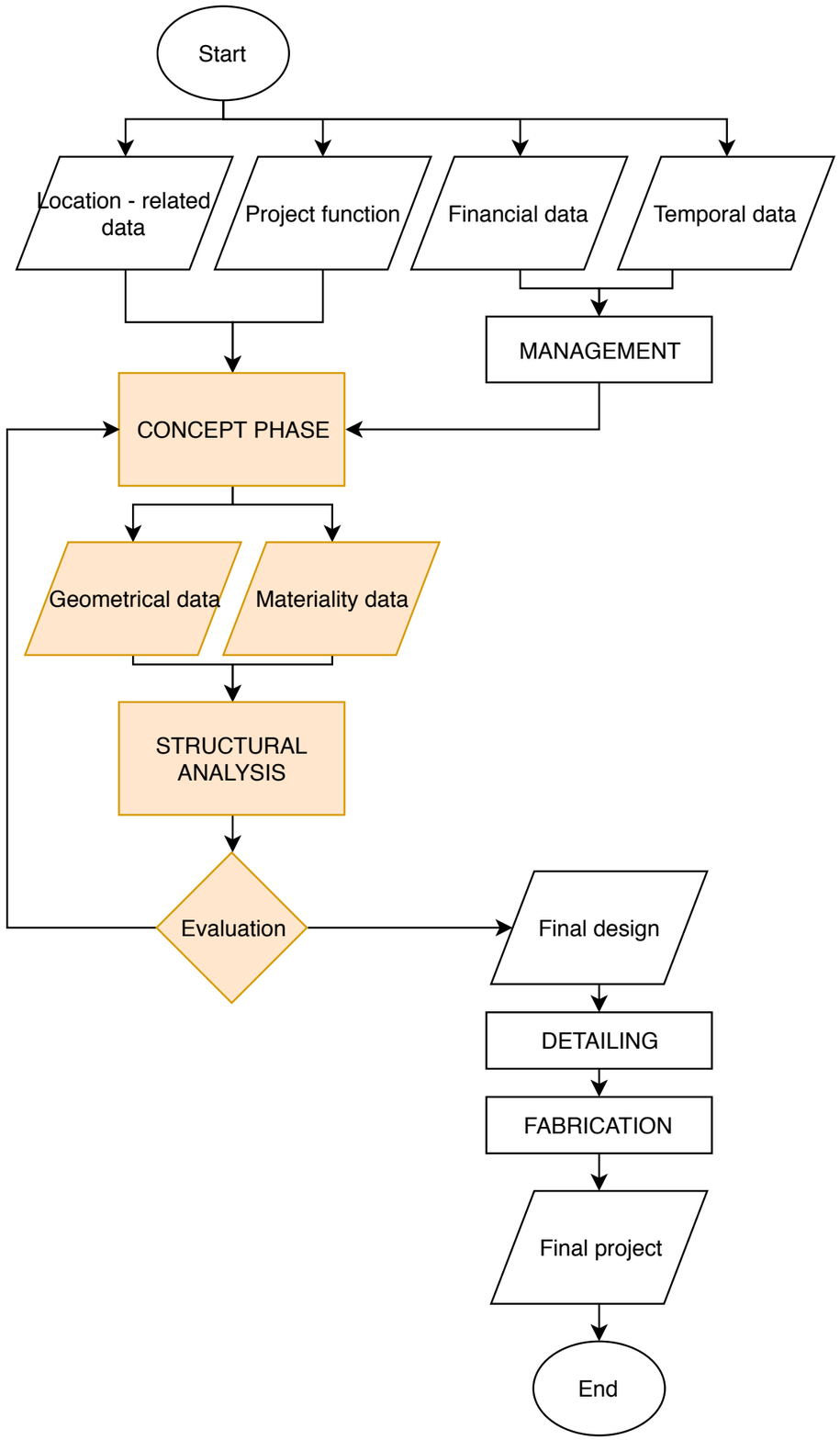






1 2 3 4 5

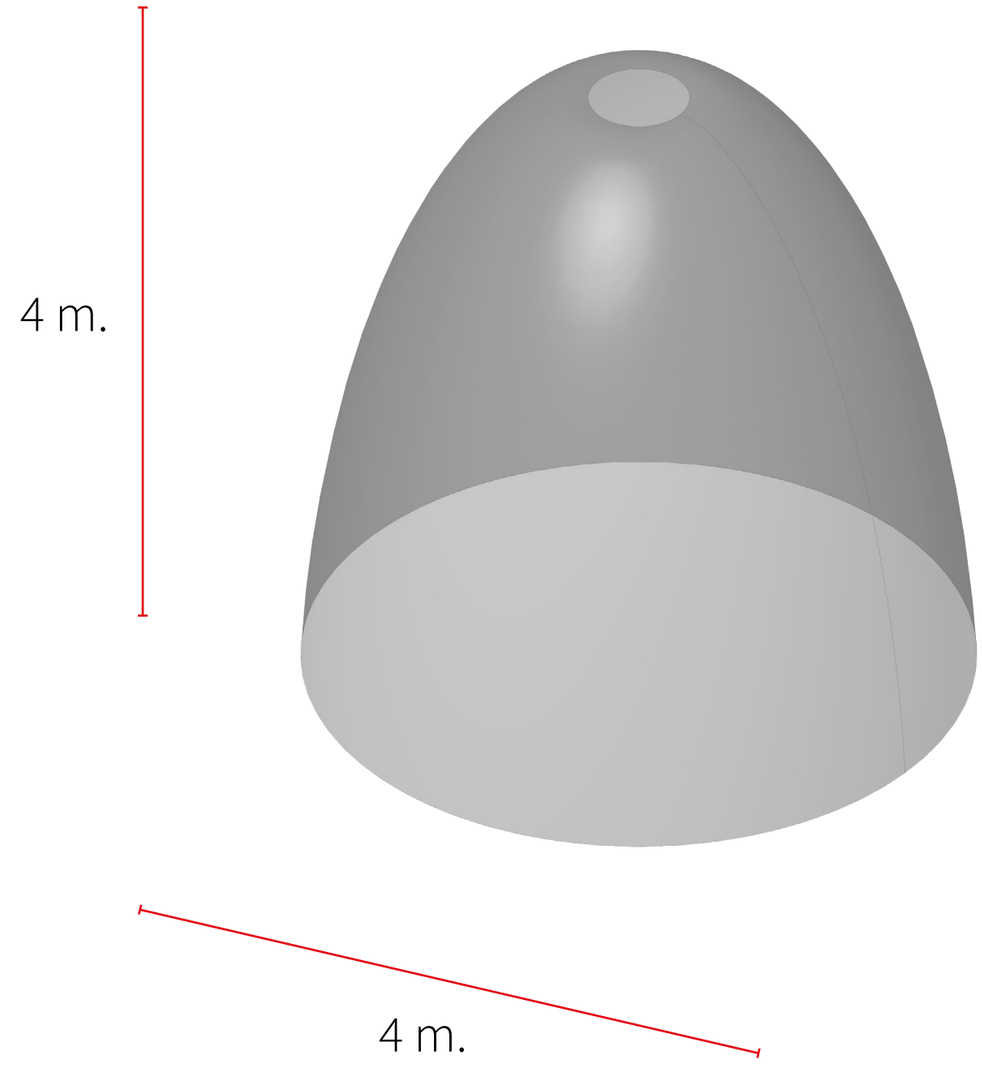
WORKFLOW



Dorze woven bamboo hut (Clarke, 2017)

1 2 3 **4** 5

SURFACE INPUT



1 2 3 **4** 5

ITERATION 1 - WM

Material:	Scots pine
Warp cross-sectional shape:	Rectangular
Warp width:	0.10 m.
Warp height:	0.03 m.
Weft cross-sectional shape:	Rectangular
Weft width:	0.10 m.
Weft height:	0.03 m.
Warp spacing:	0.3 m.
Weft spacing:	0.3 m.
Pattern:	Plain
Warp-Weft switch:	Off

1 2 3 **4** 5

ITERATION 2 - WM

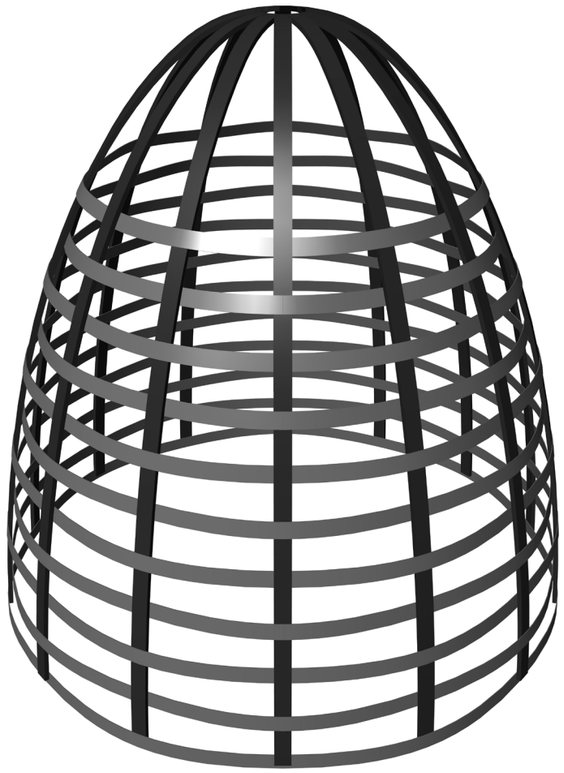
Material:	Scots pine
Warp cross-sectional shape:	Rectangular
Warp width:	0.10 m.
Warp height:	0.03 m.
Weft cross-sectional shape:	Rectangular
Weft width:	0.10 m.
Weft height:	0.005 m.
Warp spacing:	0.3 m.
Weft spacing:	0.3 m.
Pattern:	Plain
Warp-Weft switch:	Off

Minimum bending radius = 0.68 m.

1 2 3 **4** 5

ITERATION 3 - WM

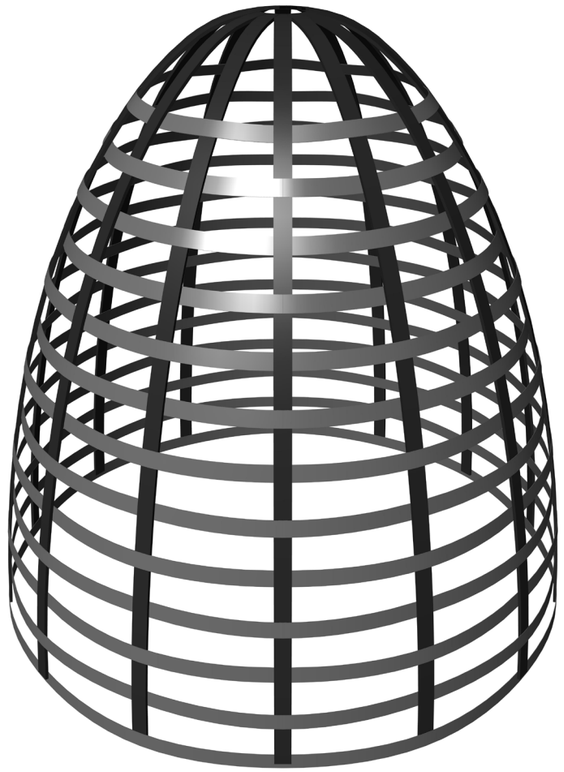
Material:	Scots pine
Warp cross-sectional shape:	Rectangular
Warp width:	0.10 m.
Warp height:	0.005 m.
Weft cross-sectional shape:	Rectangular
Weft width:	0.10 m.
Weft height:	0.03 m.
Warp spacing:	0.3 m.
Weft spacing:	0.9 m.
Pattern:	Plain
Warp-Weft switch:	Off



1 2 3 **4** 5

ITERATION 4 - WM

Material:	Scots pine
Warp cross-sectional shape:	Rectangular
Warp width:	0.02 m.
Warp height:	0.10 m.
Weft cross-sectional shape:	Rectangular
Weft width:	0.003 m.
Weft height:	0.10 m.
Warp spacing:	0.9 m.
Weft spacing:	0.3 m.
Pattern:	Plain
Warp-Weft switch:	Off



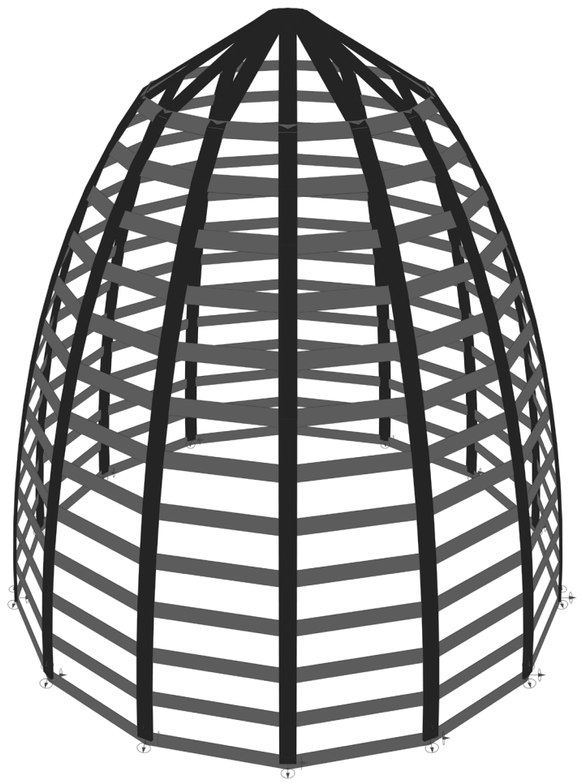
1 2 3 4 5

ITERATION 4 - SA

Interior - Exterior
Selection: Interior

Cover switch: Off

Loadcase: 0

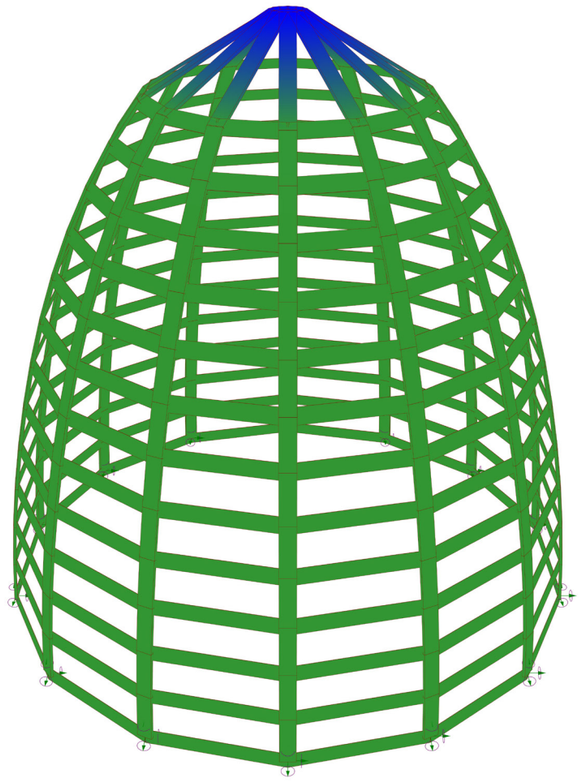


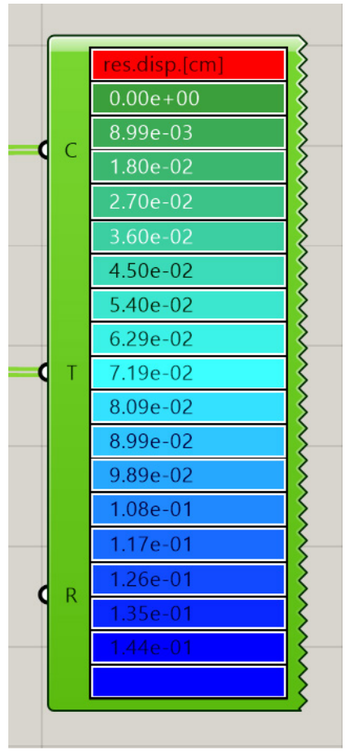
ITERATION 4 - SA

Interior - Exterior
Selection: Interior

Cover switch: Off

Loadcase: 0



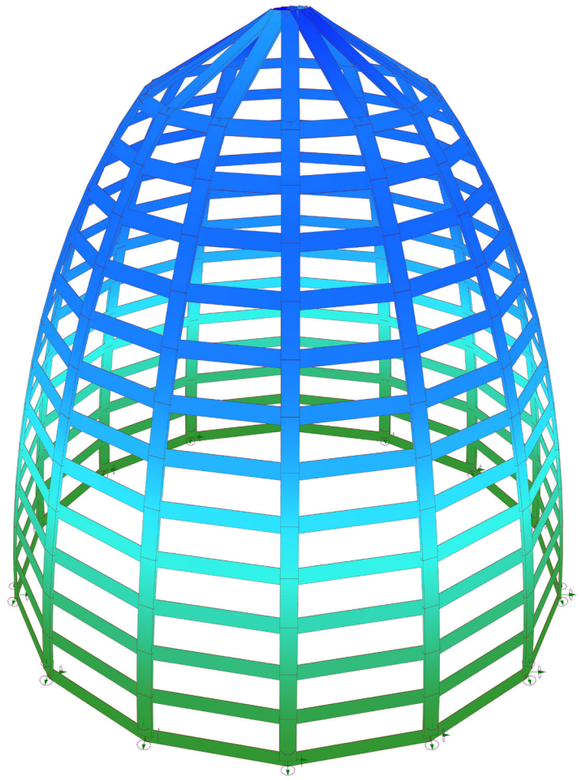


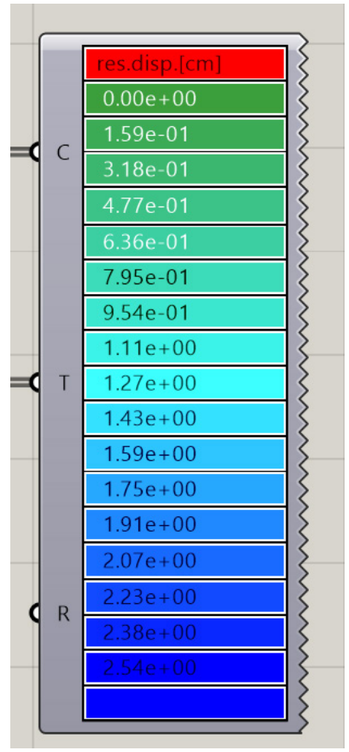
ITERATION 4 - SA

Interior - Exterior
Selection: Exterior
Location: Amsterdam
Wind vector: {1,1,0}

Cover switch: Off

Loadcase: 2





1 2 3 4 5

ITERATION 5 - WM

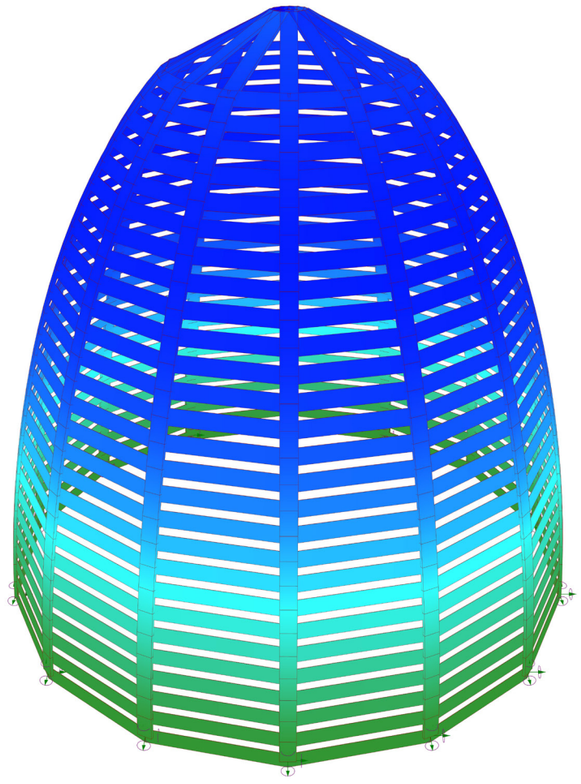
Material:	Scots pine
Warp cross-sectional shape:	Rectangular
Warp width:	0.02 m.
Warp height:	0.10 m.
Weft cross-sectional shape:	Rectangular
Weft width:	0.003 m.
Weft height:	0.10 m.
Warp spacing:	0.9 m.
Weft spacing:	0.15 m.
Pattern:	Plain
Warp-Weft switch:	Off

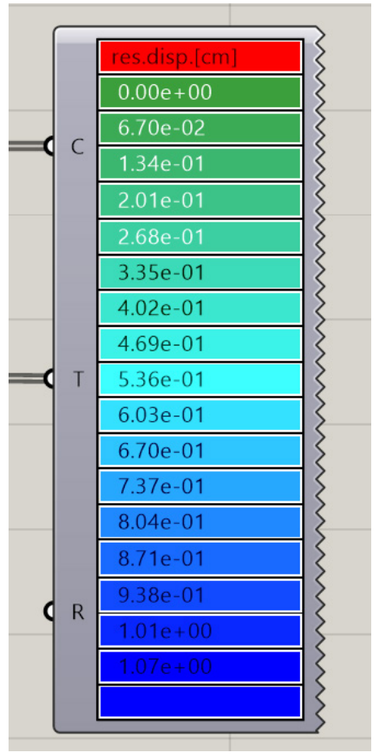
ITERATION 5 - SA

Interior - Exterior
Selection: Exterior
Location: Amsterdam
Wind vector: {1,1,0}

Cover switch: Off

Loadcase: 2





1 RESEACH FRAMEWORK

2 INTRODUCTION TO WEAVING

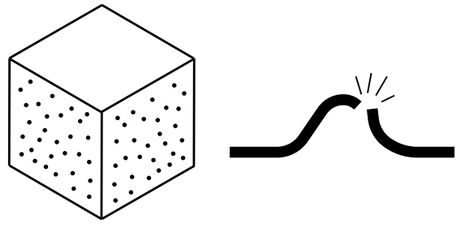
3 COMPUTATIONAL TOOLS

4 CASE STUDY

5 CONCLUSIONS

CONCLUSIONS

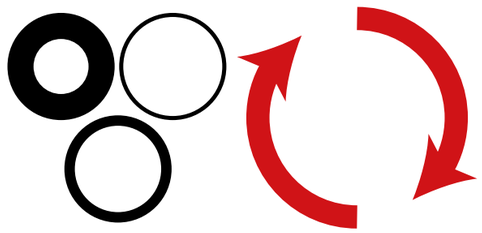
I. MATERIALITY



CONCLUSIONS

I. MATERIALITY

II. ADVANTAGES OF PARAMETRIC PROCESS

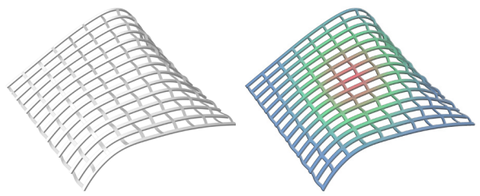


CONCLUSIONS

I. MATERIALITY

II. ADVANTAGES OF PARAMETRIC PROCESS

III. EFFECT OF WEAVE PARAMETERS ON BEHAVIOUR



CONCLUSIONS

I. MATERIALITY

II. ADVANTAGES OF PARAMETRIC PROCESS

III. EFFECT OF WEAVE PARAMETERS ON BEHAVIOUR

IV. LIMITATIONS

THANK YOU!