A COMPUTATIONAL APPROACH FOR RENEWABLE ARCHITECTURE

A Generative Design Approach
Using Bioplastics and Earth
For a Bus Station Design

Master of Science (MSc) Thesis

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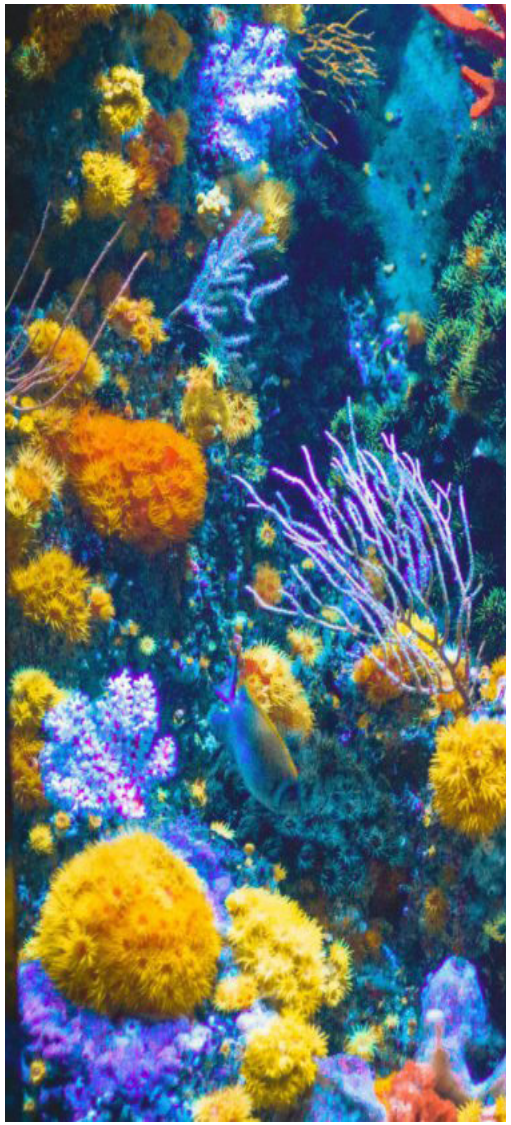
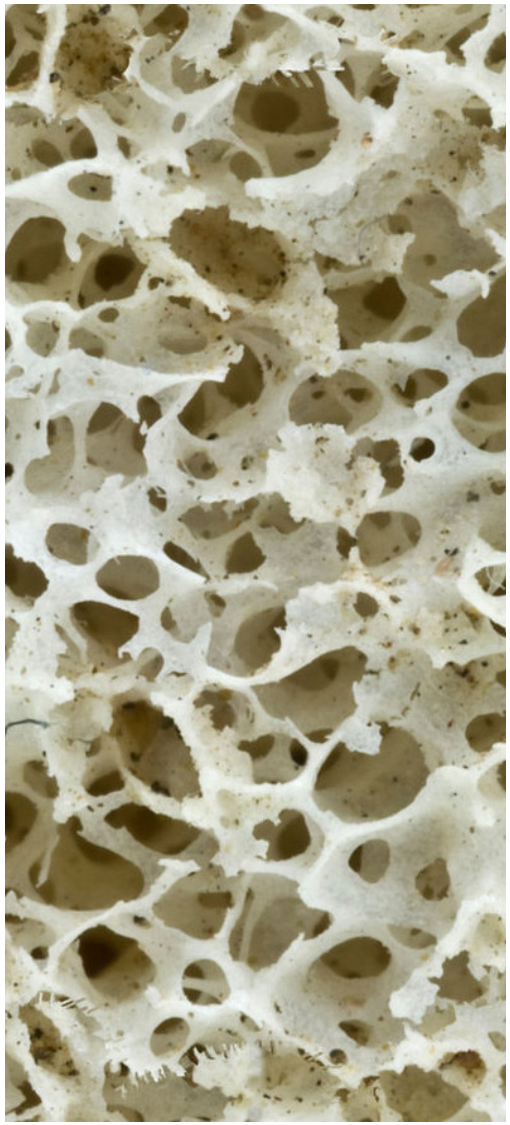
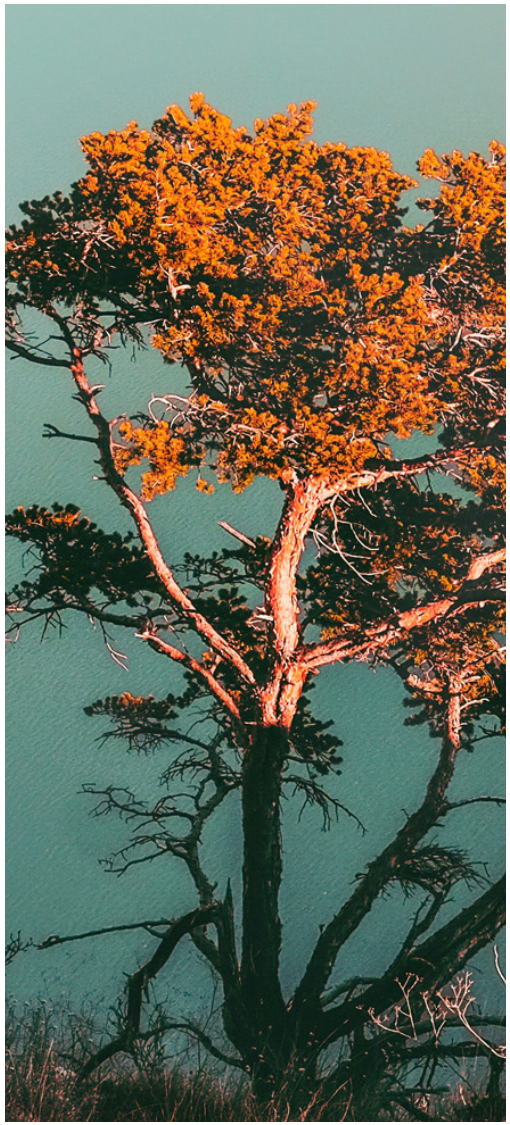
Building Technology

INSPIRATION

F. Staud, National Geographic. National Geographic, 2014.
Coral Reef Photograph. National Capital Coalition, 2018.
M. Manske, Human hip bone texture. Wikipedia Commons, 2008.
C. Gottardi, Tree. Unsplash.

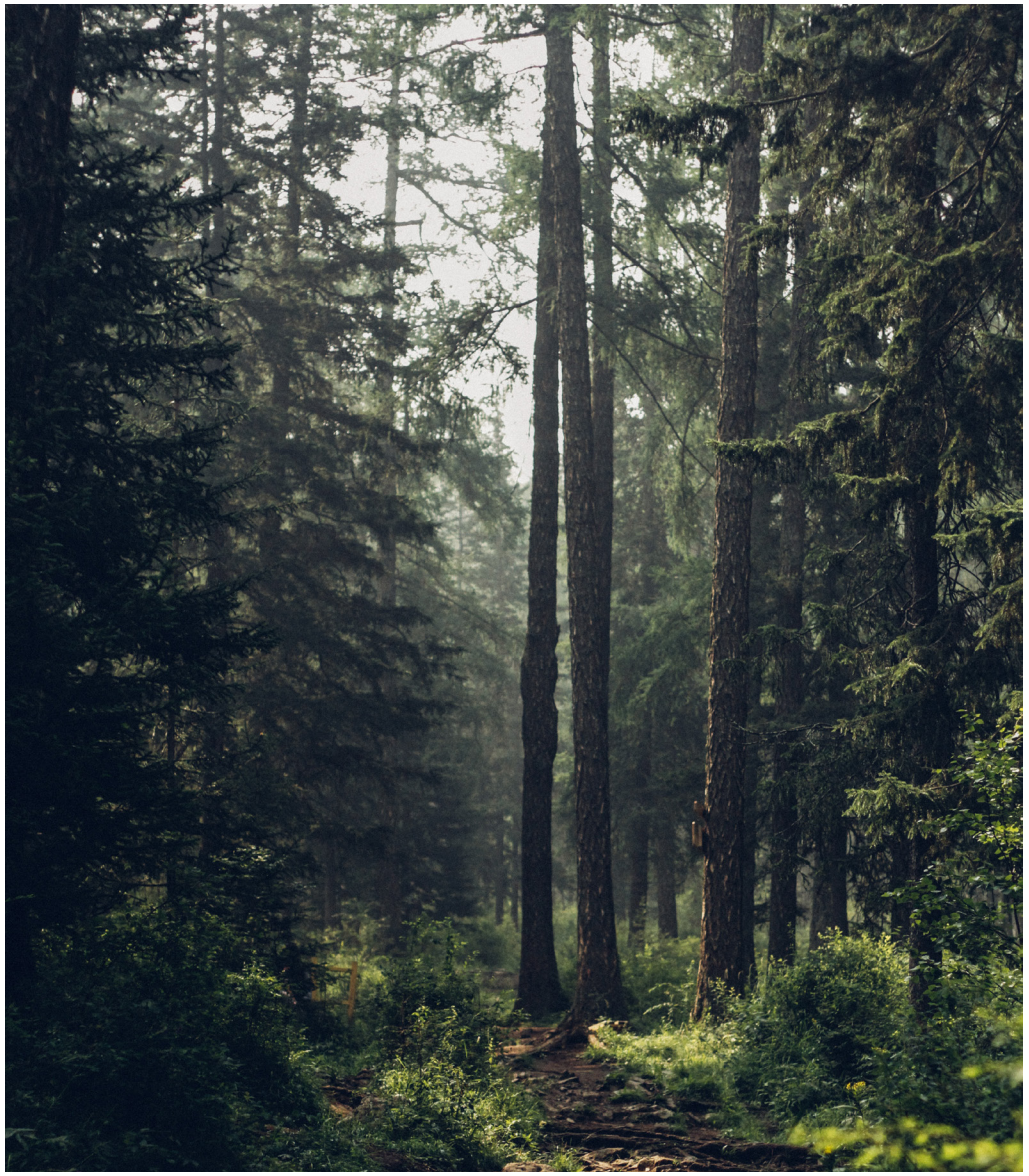
R. Olson, Plastic Pollution. National Geographic, 2018.

V. Featherstone-Witty, Don’t eat me! National Geographic, 2016.

N. Garrido, Qatar National Convention Centre / Arata Isozaki. ArchDaily.

F. Staud, National Geographic. National Geographic, 2014.

A. Spratt, Hong Kong. Unspalsh.



D. Degi, Bogd Khan Mountain, Mongolia. Unsplash.

RESEARCH QUESTIONS

1. How to compute an architectural form in consideration of the building units and material performance of the units?

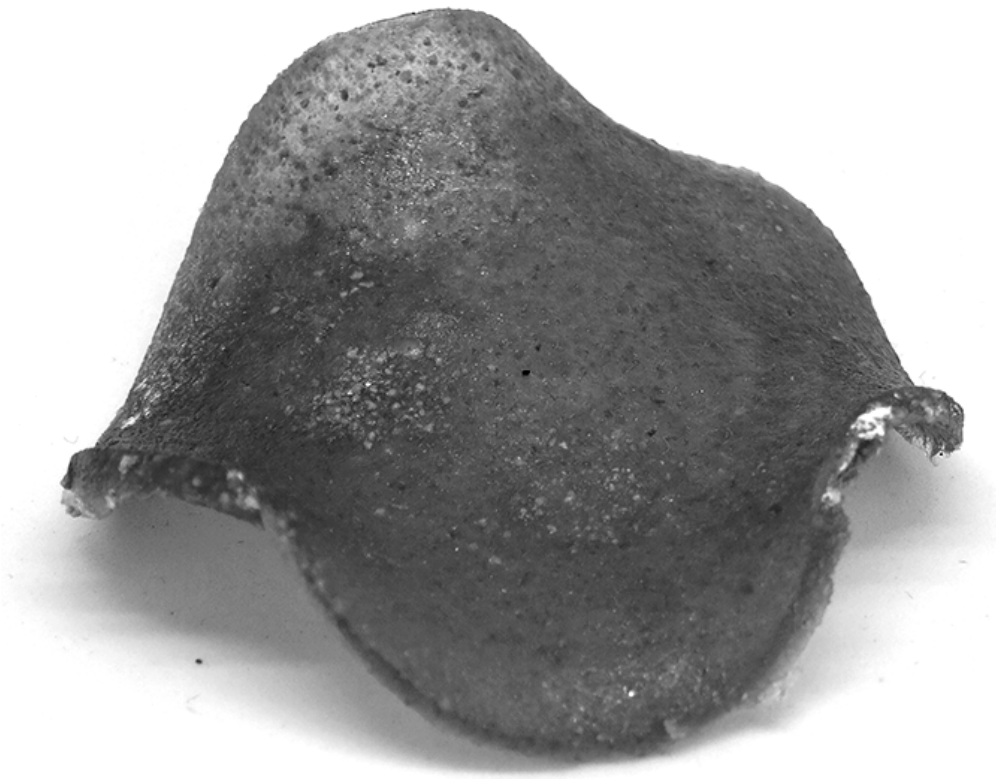
2. How to optimize material use in the given design problem?

RESEARCH BY DESIGN

R. Hooker, By the Bus Stop. Fubiz, 2012.

MATERIALITY

D. H. Chamberlin, New adobe bricks. D Holmes Chamberlin Jr Architect LLC, 2017.



BIOPLASTICS

Bioplastic from Foodwaste. Materialibility.

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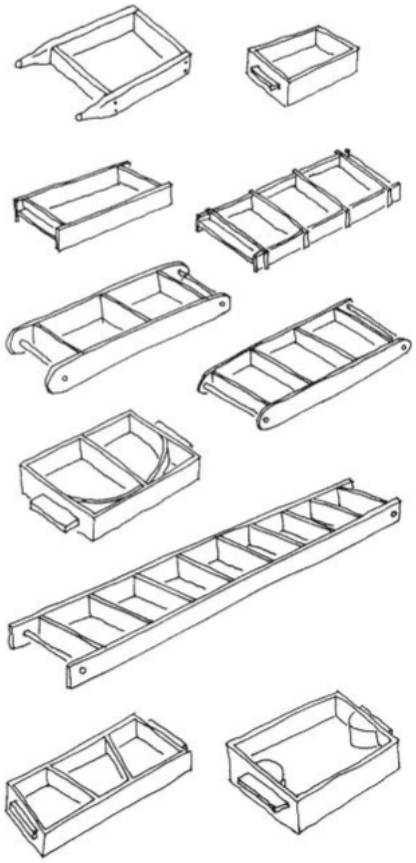
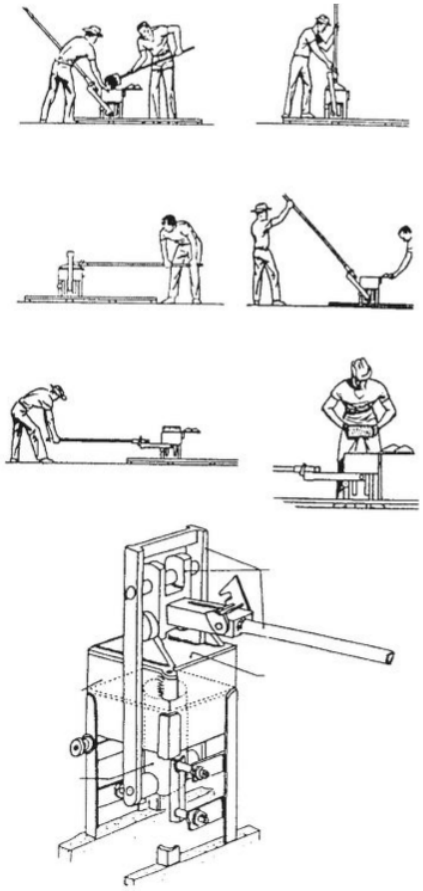


Typical moulds examples for adobe



"The best-known press worldwide in the CINVA Ram, developed in Colombia by the Chilean engineer Ramirez"

[1] G. Minke, "Working with Earthen Blocks," in Building with Earth, Birkhaeuser, 2006.

BIOPLASTIC

BIOPLASTIC?

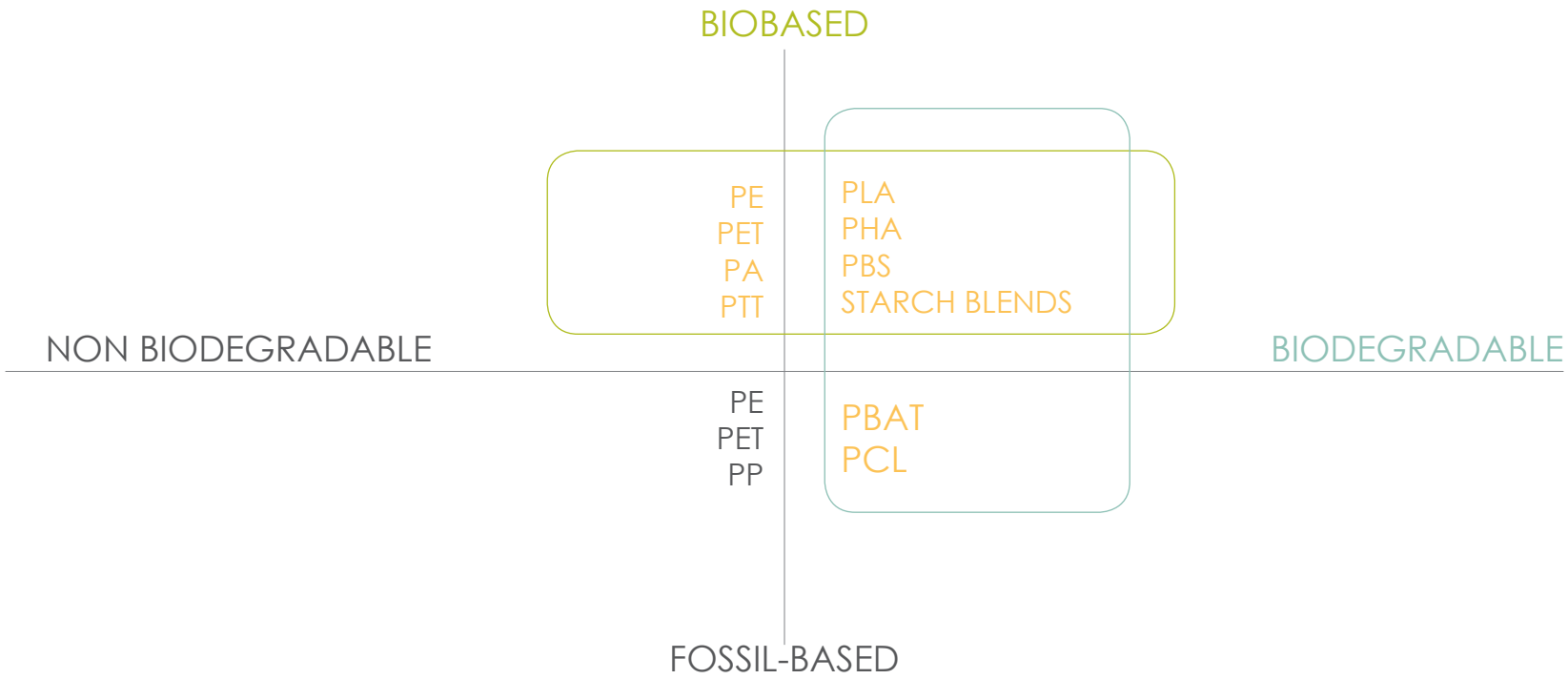


Figure 2.3: Bioplastic chart based on biobased and biodegradability of traditional plastics. Redrawn by the author

BIOPLASTIC?

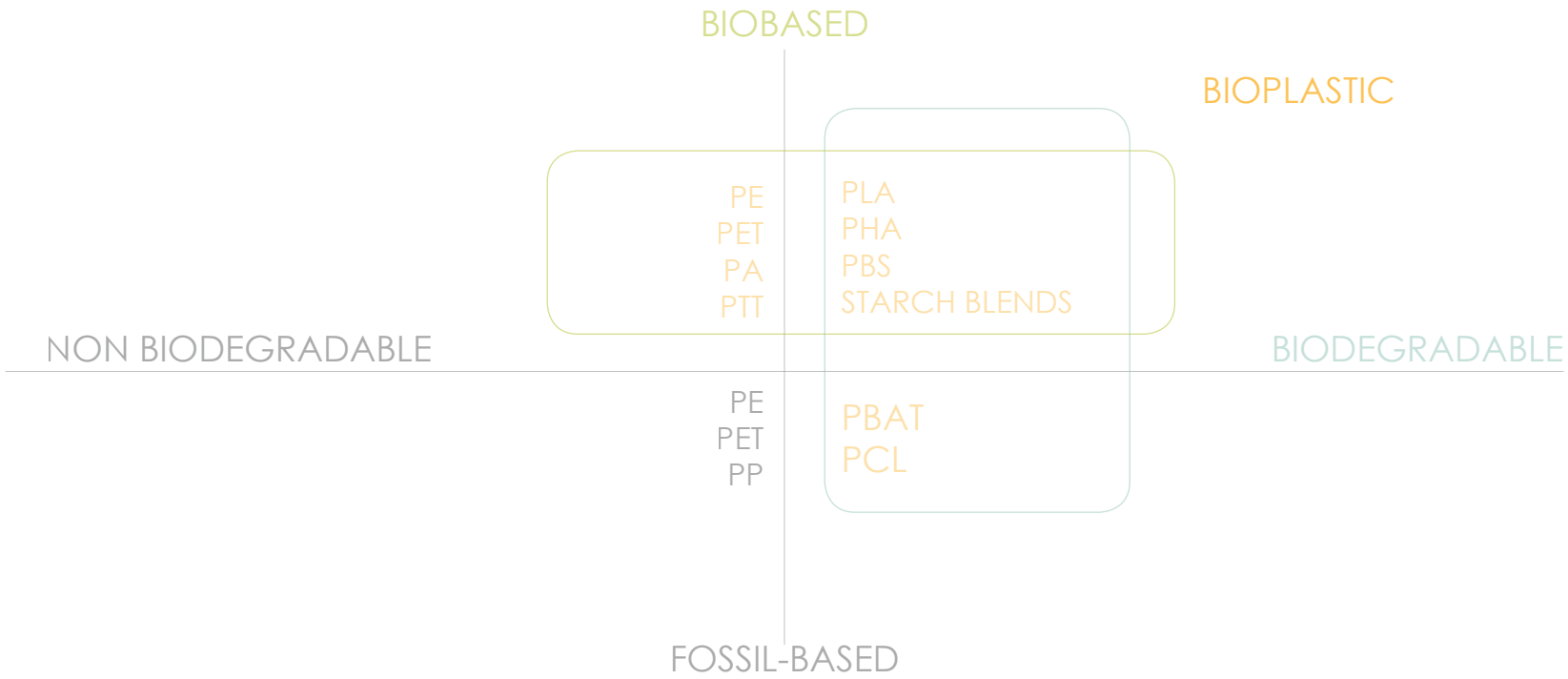


Figure 2.3: Bioplastic chart based on biobased and biodegradability of traditional plastics. Redrawn by the author

A. R. Bagheri, C. Laforsch, A. Greiner, and S. Agarwal, "Fate of So-Called Biodegradable Polymers in Seawater and Freshwater," Glob. Challenges, vol. 1, no. 4, p. 1700048, 2017.

Figure 3.3: Tools and ingredients used.

E. Zakharov, Transparent glass with clean mineral water isolated on white background. 2019.

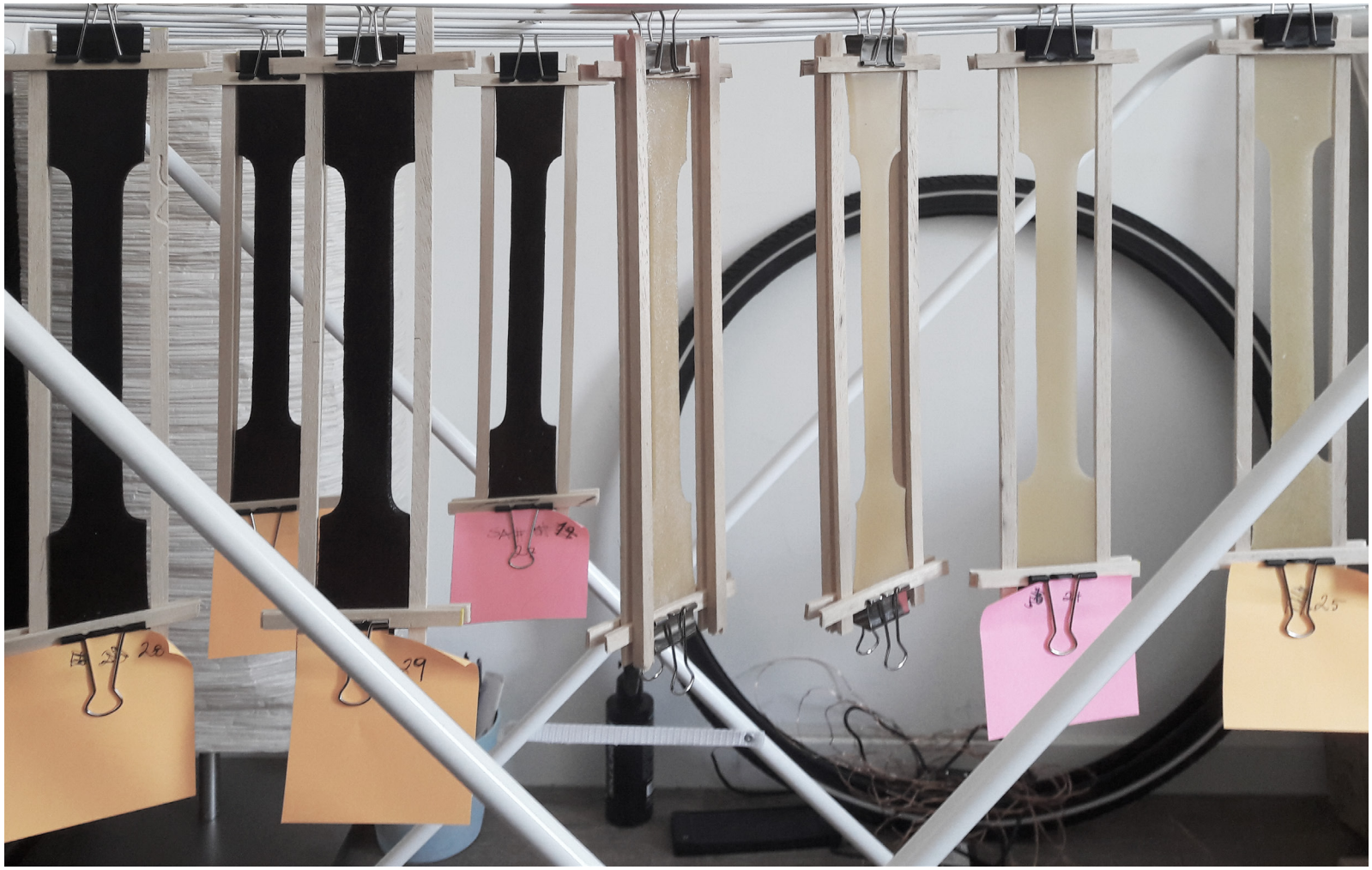
Samsung CTR164NC01 57.5cm 4 Zone Electric Cooktop. .

TEST SAMPLES

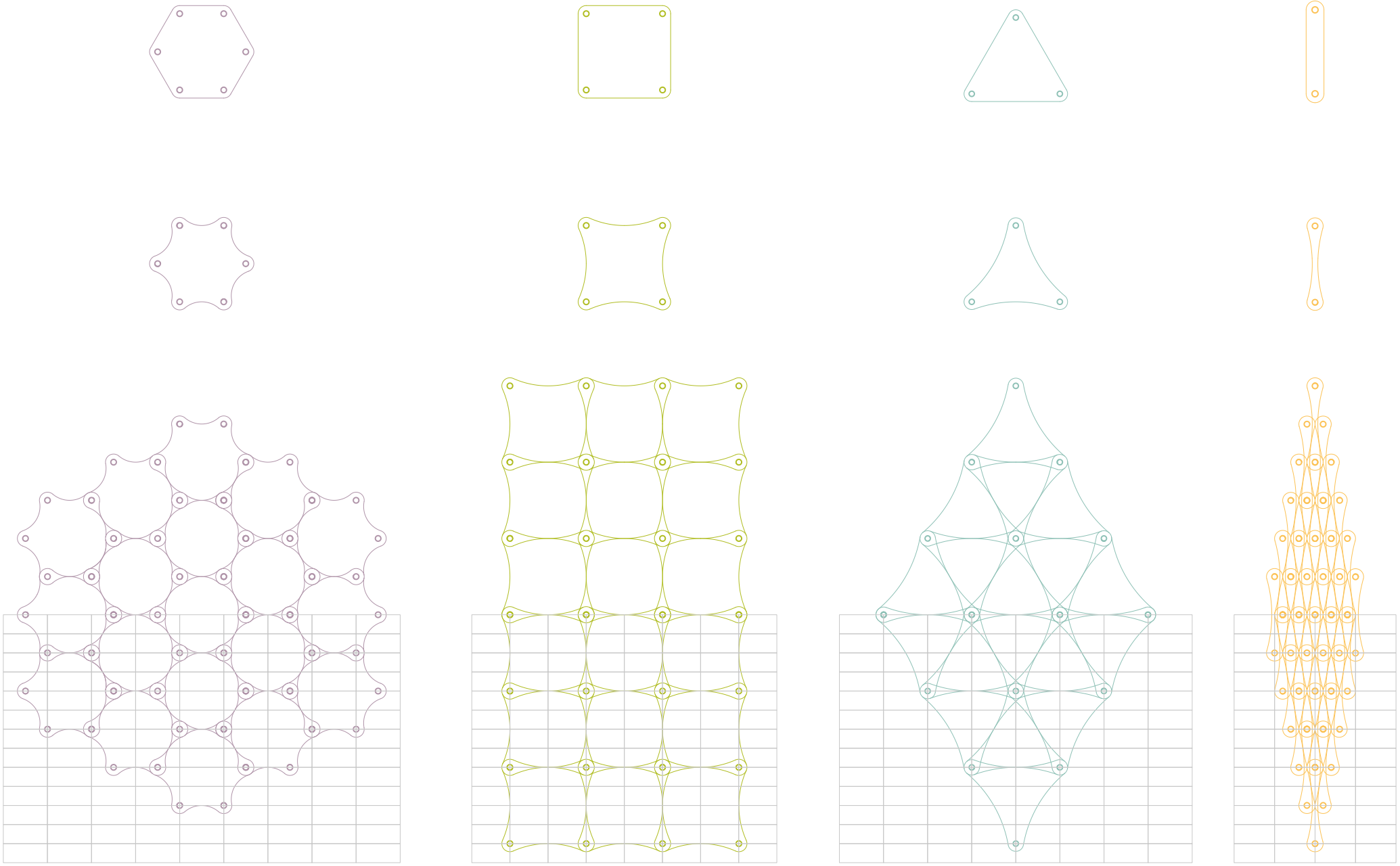
	Tensile Strength		Yield Strength		Young's Modulus		Glycerine	Water	Gelatine	Coffee
	[MPa]	SD [±]	[MPa]	SD [±]	[MPa]	SD [±]	(g)	(g)	(g)	(g)
Type 01	1,64	1,07	4,74	3,16	3,55	0,59	1	50	23	4
Type 02	18,78	14,54	23,04	14,36	14,44	10,50	1	50	23	2
Type 03	17,88	15,73	23,04	14,79	7,39	4,63	1	30	23	-
Type 04	32,71	19,32	33,59	18,48	11,41	7,82	1	50	23	-

FAILED SAMPLES

IMPROVING CURING PROCESS



PANEL DESIGN OPTIONS



TESTING PANELS

SPECIMEN 2, 3 | SPECIMEN 4 | SPECIMEN 5,6 | SPECIMEN 7

	F_{max} N	dL at F_{max} mm	F_{Break} N	dL at break mm	a_0 mm	b_0 mm	S_0 mm²	Gelatine g	Glycerine g	Water g	Coffee g
Specimen 2	190,11	11,66			100,00	100,00	10000,00	207,00	9,00	450,00	18,00
Specimen 3	171,65	39,89	150,61	54,92	100,00	100,00	10000,00	207,00	9,00	450,00	-
Specimen 4	710,53	33,58	710,53	33,58	100,00	100,00	10000,00	276,00	12,00	600,00	-
Specimen 5	103,91	26,04			100,00	100,00	10000,00	207,00	9,00	450,00	-
Specimen 6	115,47	29,20			100,00	100,00	10000,00	207,00	9,00	450,00	-
Specimen 7	205,96	46,91			100,00	100,00	10000,00	207,00	9,00	450,00	-

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OPTIMIZATION METHODS

OPTIMALITY CRITERIA METHODS

HEURISTIC OR INTUITIVE METHODS

OPTIMIZATION METHODS

OPTIMALITY CRITERIA METHODS	HEURISTIC OR INTUITIVE METHODS
Homogenization	Fully Stressed Design
Solid Isotropic Material with Panelization(SIMP)	Computer-Aided Optimization (CAO)
Level Set Method	Soft Kill Option (SKO)
Growth Method for Truss Structures	Evolutionary Structural Optimization (ESO)
	Bidirectional ESO (BESO)
	Sequential Element Rejection & Admission
	Isolines / Isosurfaces Topology Design (ITD)

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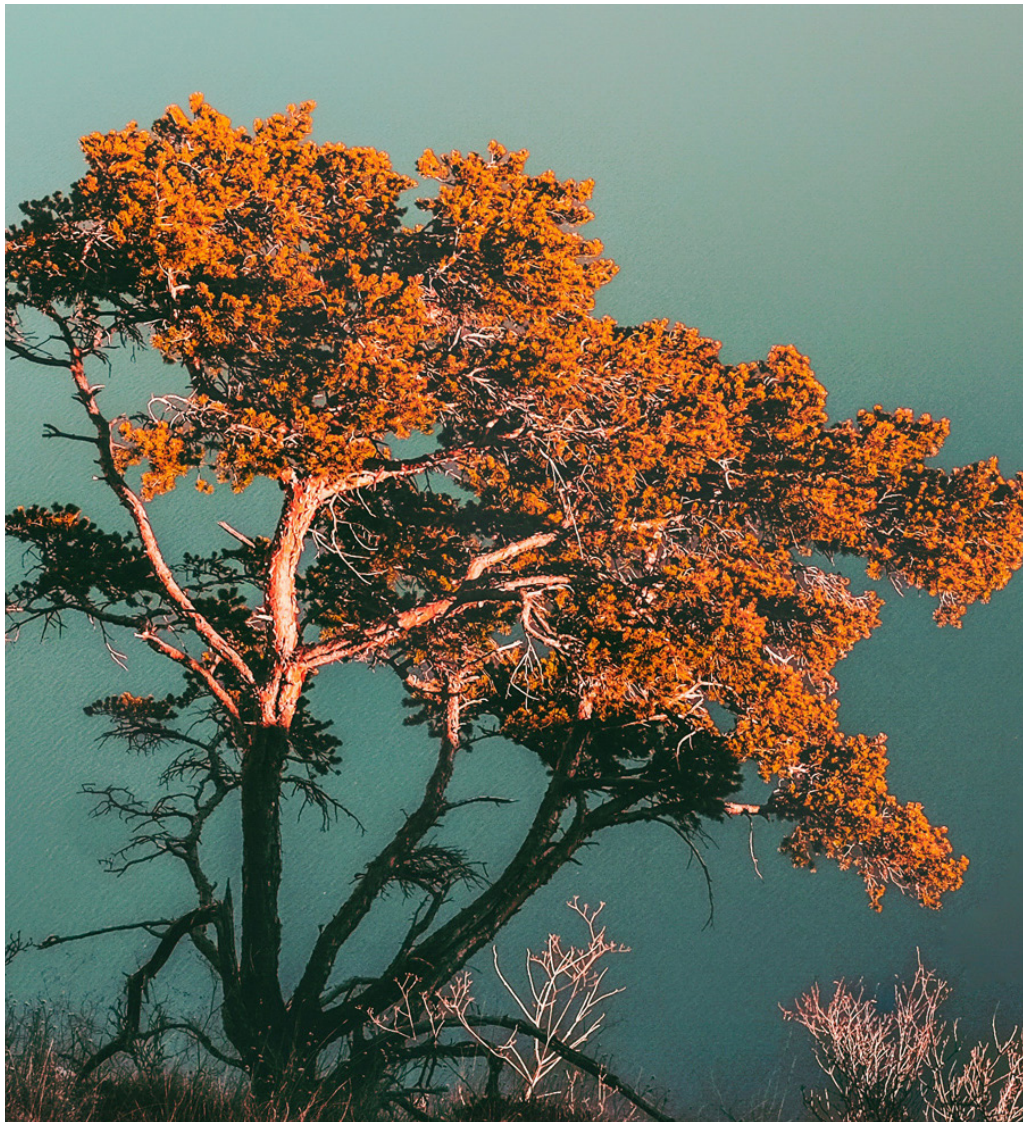
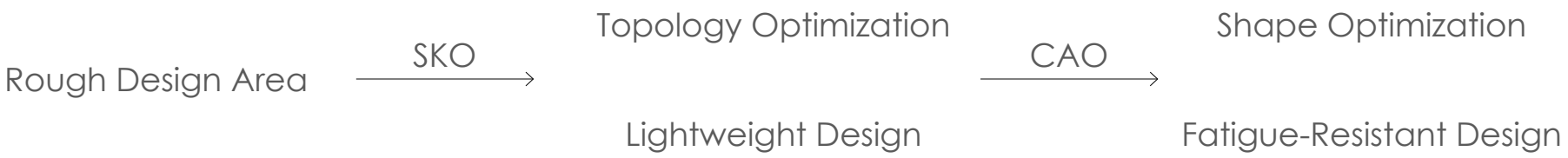
SKO

CAO

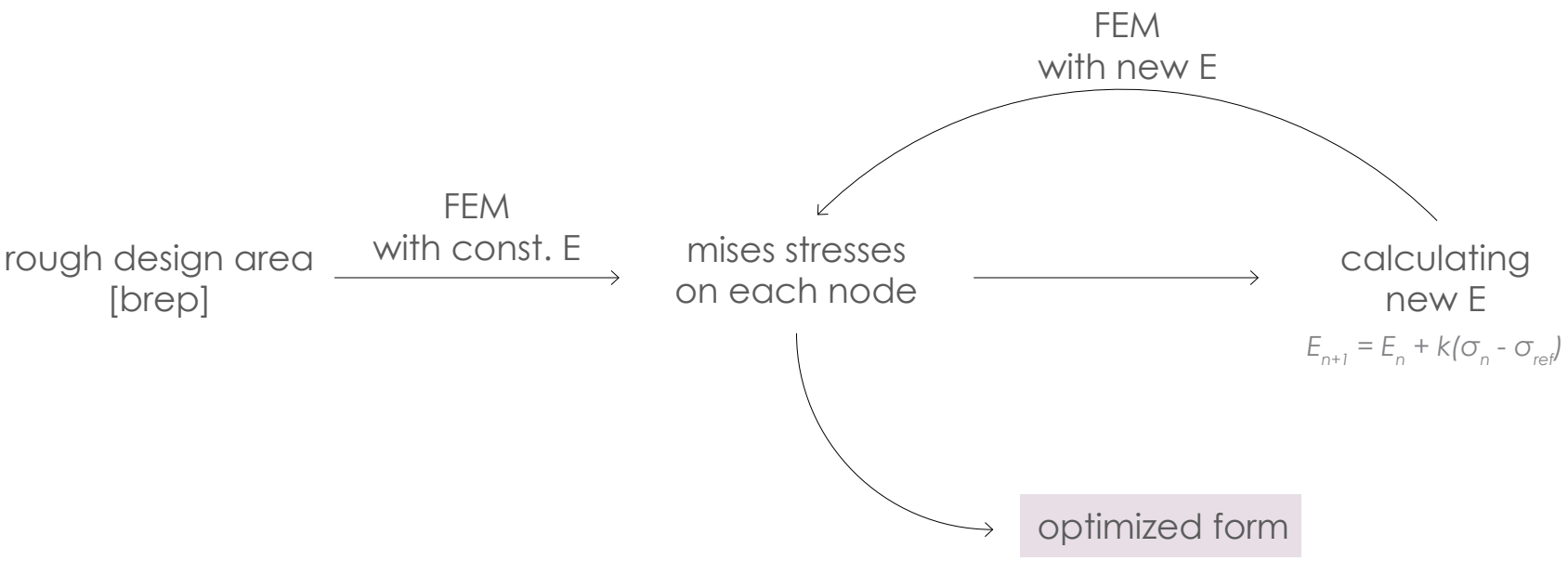


M. Manske, Human hip bone texture. Wikipedia Commons, 2008.
C. Gottardi, Tree. Unsplash.

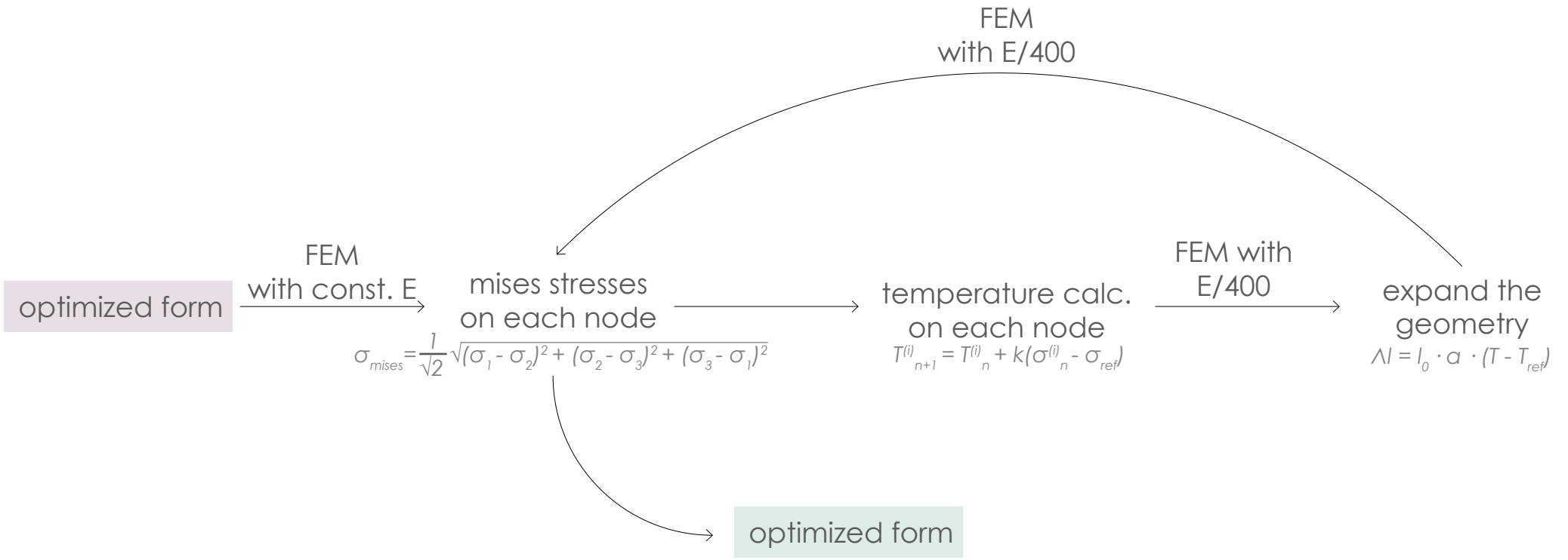
RECOMMENDED WORKFLOW



SOFT KILL OPTIMIZATION (SKO)



COMPUTER AIDED OPTIMIZATION (CAO)



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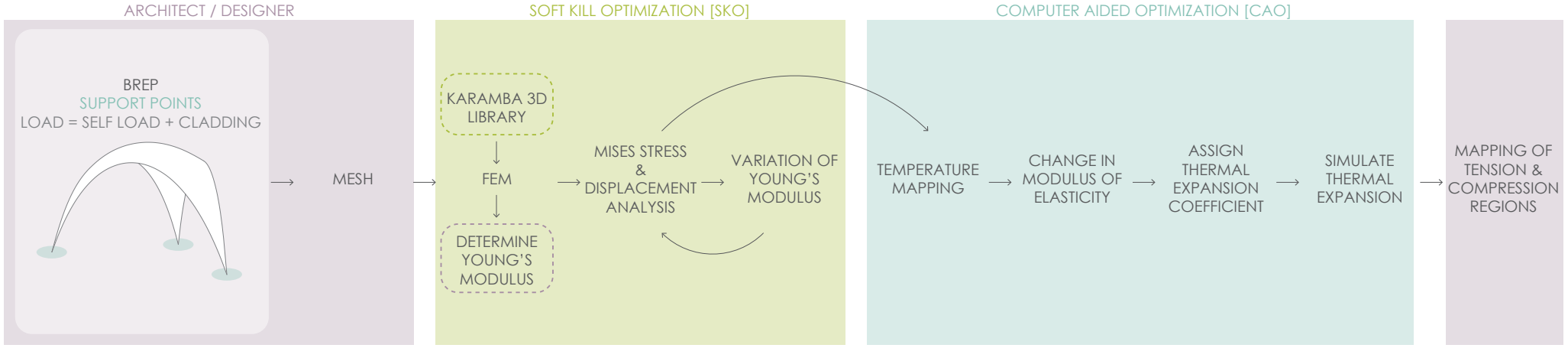
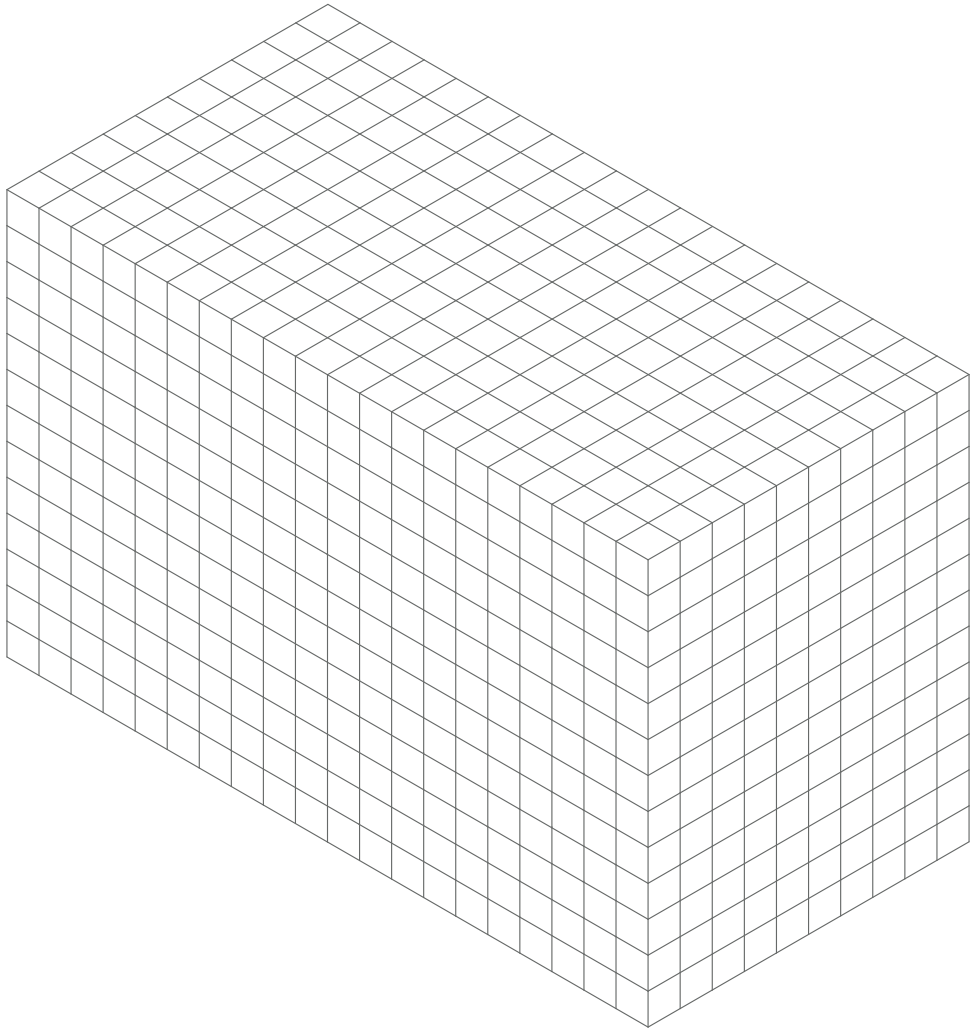
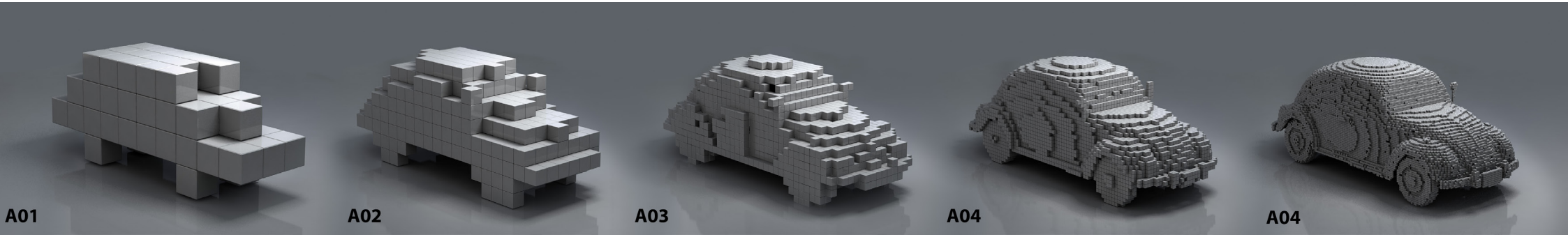
INITIAL APPROACH



FINAL APPROACH

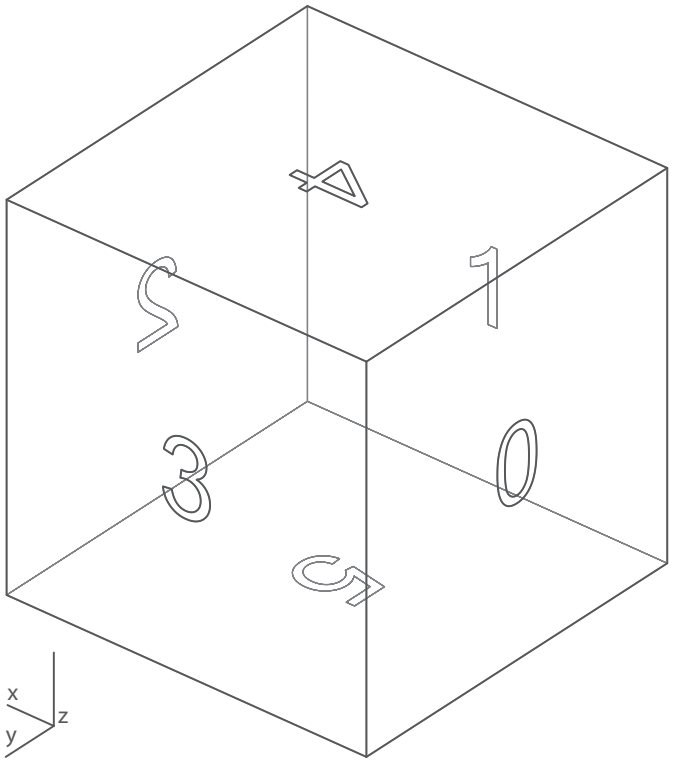


VOXELIZATION



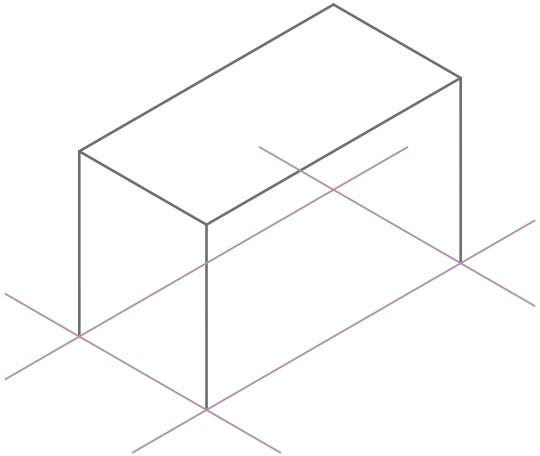
A01 – A05 are examples for different resolutions of Voxels may appear. Bilder Zucht, 2010.

VOXEL DESIGN



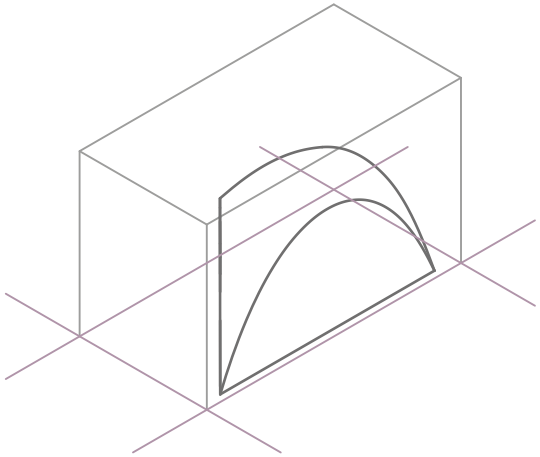

```
self.x = int
self.y = int
self.z = int
self.index = self.x, self.y, self.z

self.vox = rg.Box()

self.active = bool

self.support = bool

self.center = rg.Point3d()

self.adjacency=[bool,bool,bool,bool,bool,bool]

self.totalForceX = float
self.totalForceY = float
self.totalForceZ = float

self.totalStressX = float
self.totalStressY = float
self.totalStressZ = float
self.totalStress = self.totalStressX + self.totalStressY + self.totalStressZ
```

INPUTS



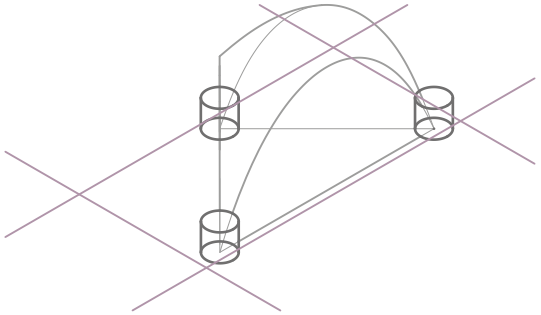
ROUGH DESIGN AREA

self.index
self.vox
self.active
self.support
self.center
self.adjacency
self.isEdge
self.isCorner



AREA THAT NEEDS TO BE REMOVED

self.index
self.vox
self.active
self.support
self.center
self.adjacency
self.isEdge
self.isCorner

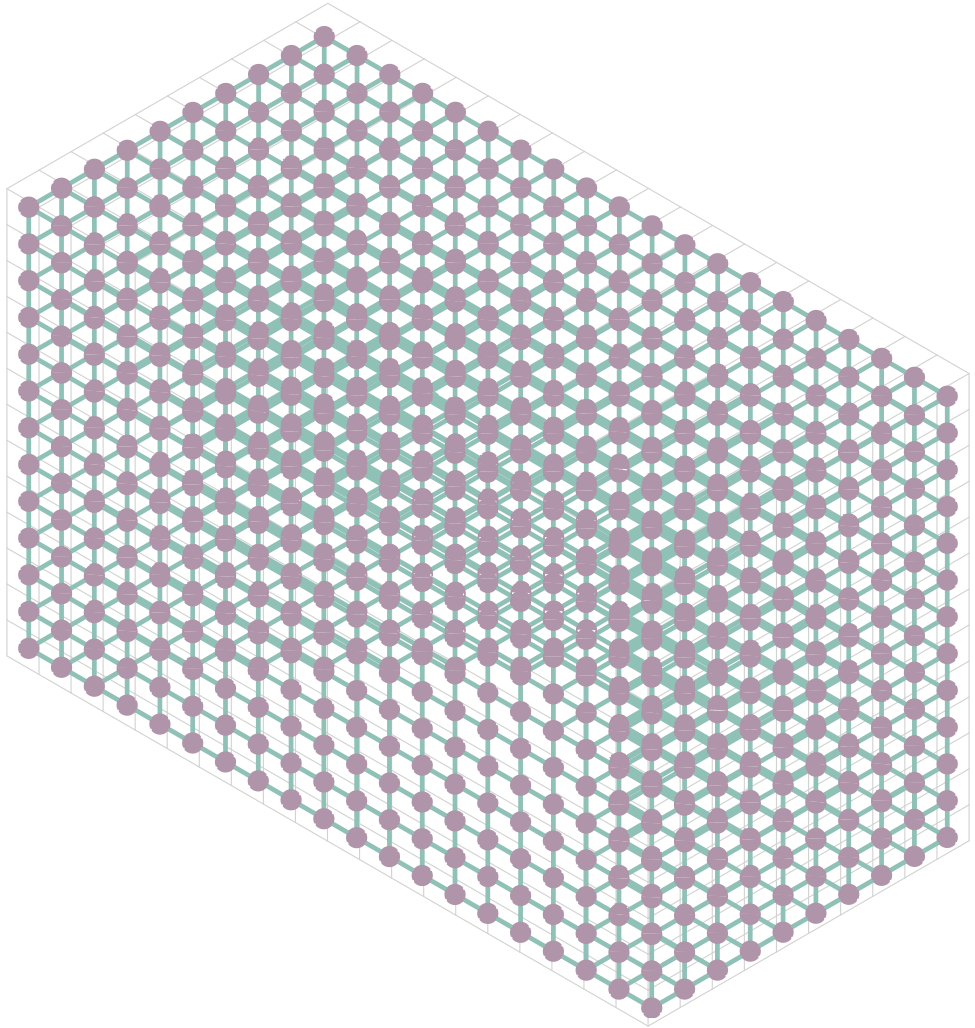


SUPPORT AREAS

self.index
self.vox
self.active
self.support
self.center
self.adjacency
self.isEdge
self.isCorner

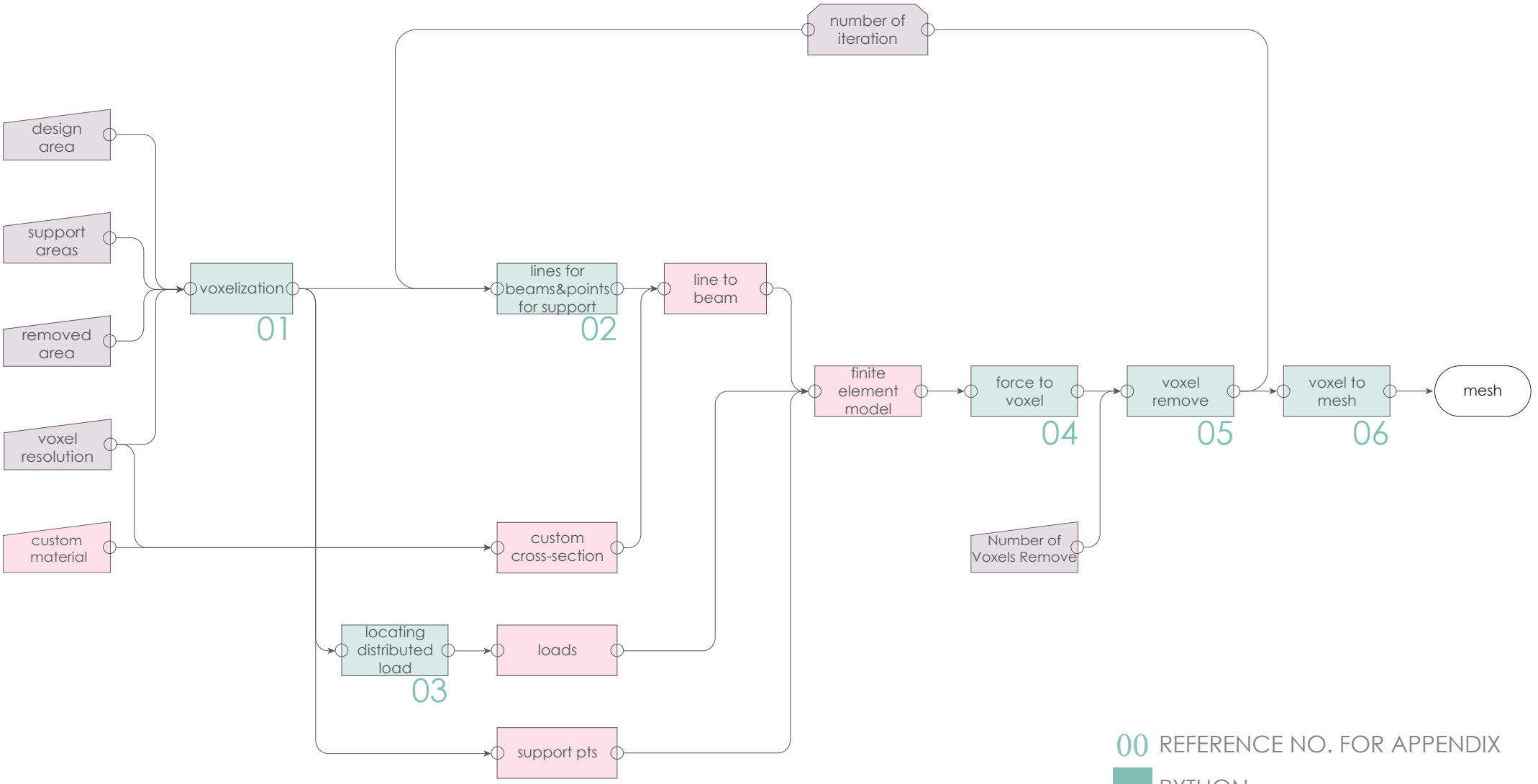
TRUE
FALSE

MESH TO BEAMS

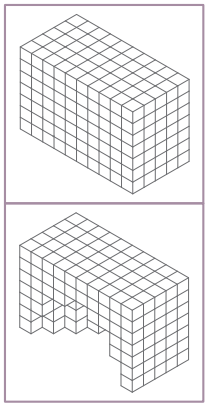
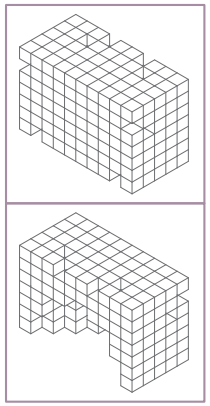
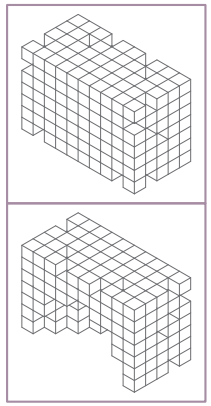
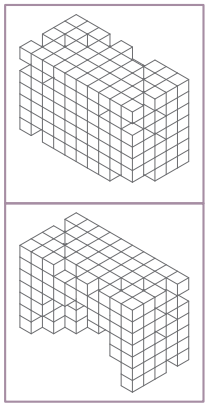
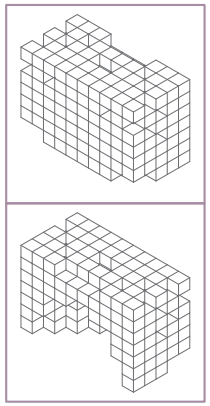
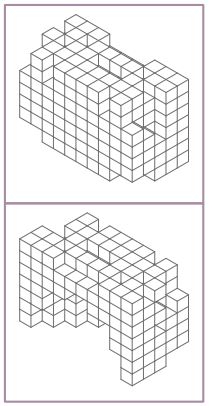
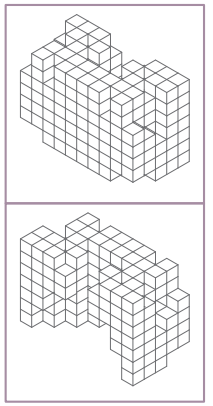


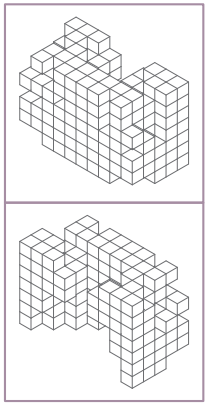
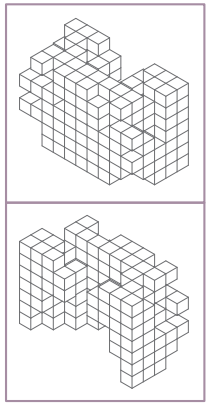
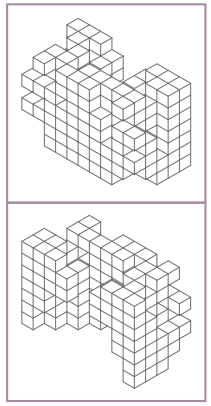
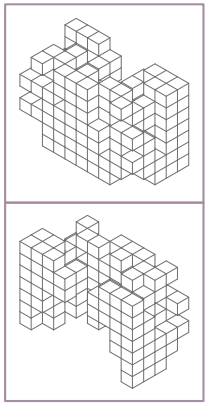
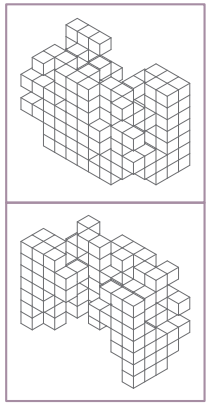
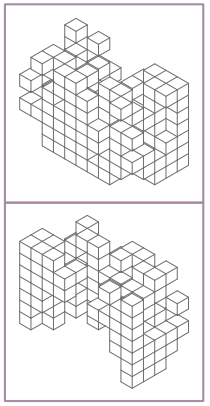
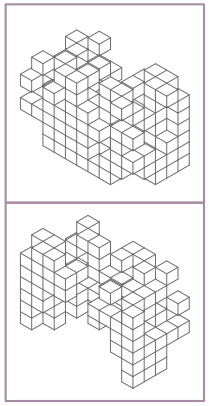
Center Of Voxels (self.Center)
Lines to Beams
Voxel Silhouette

OVERALL FLOWCHART

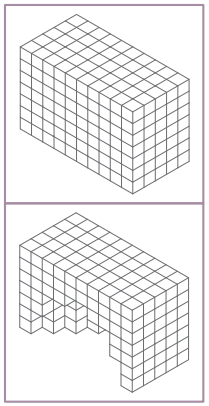
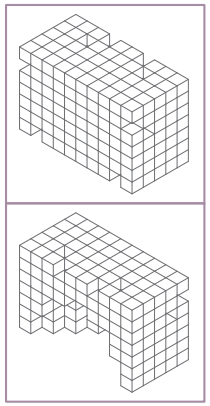
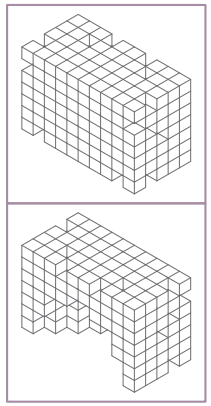
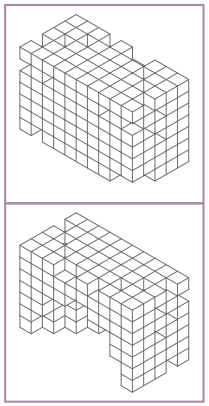
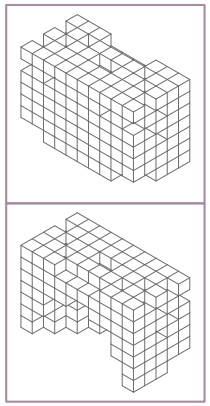
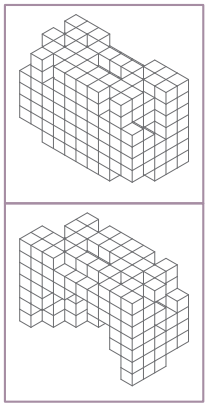
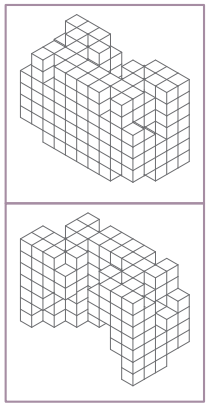


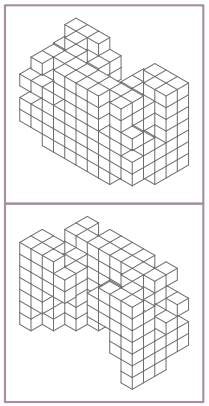
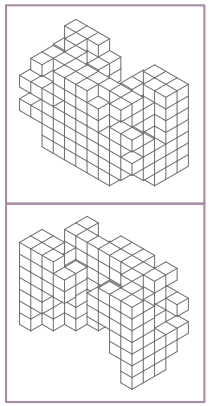
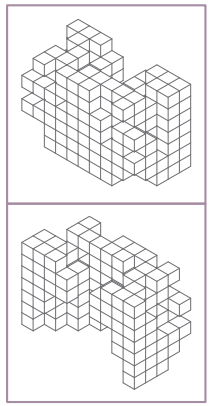
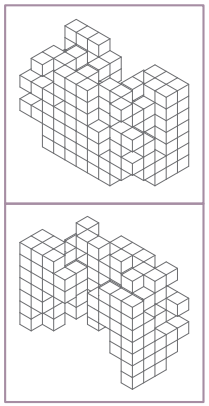
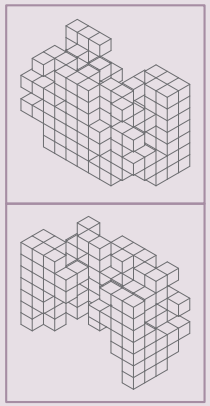
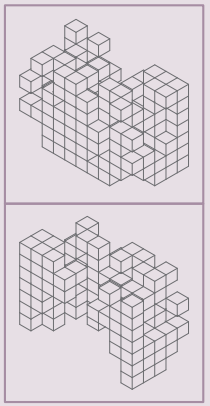
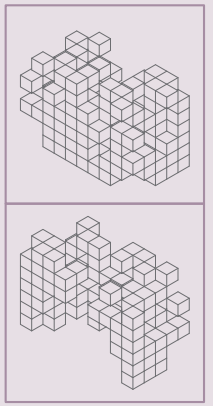
LOW - RESOLUTION ITERATIONS

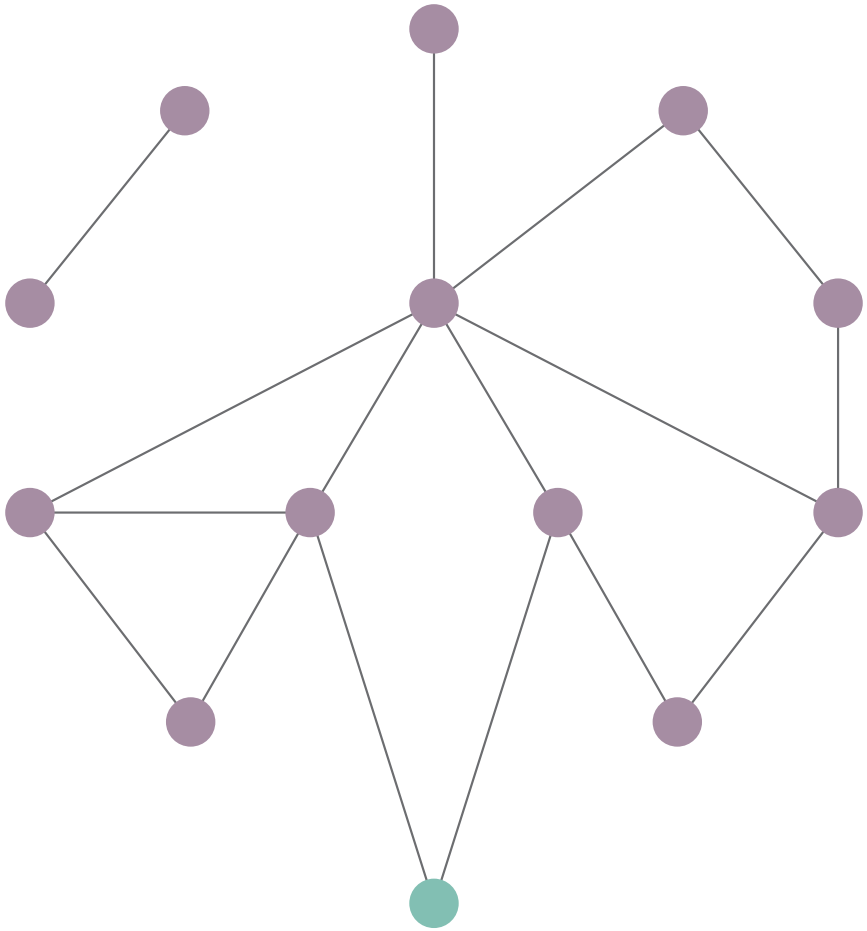








LOW - RESOLUTION ITERATIONS

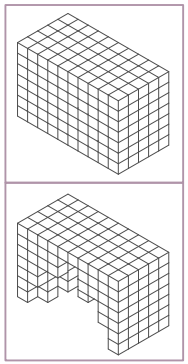
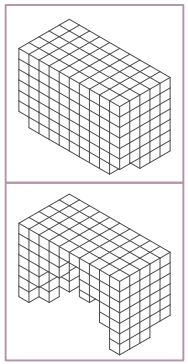
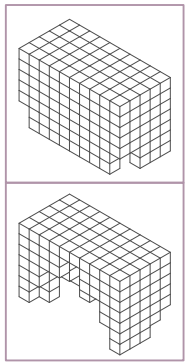
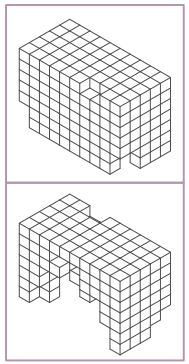
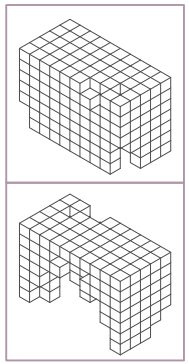
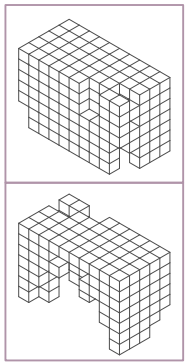
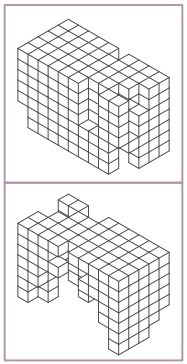
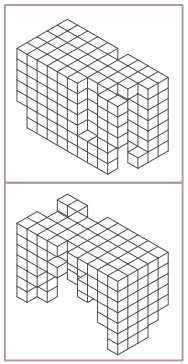








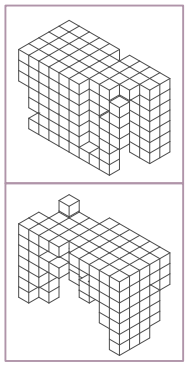
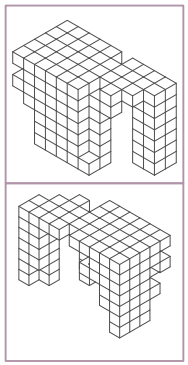
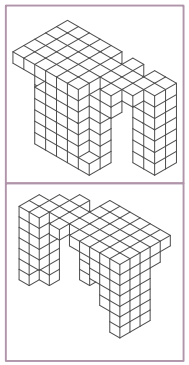
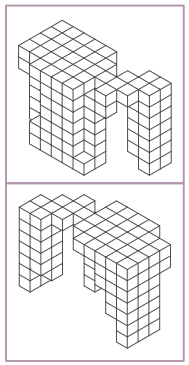
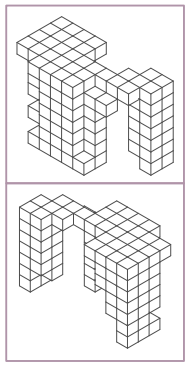
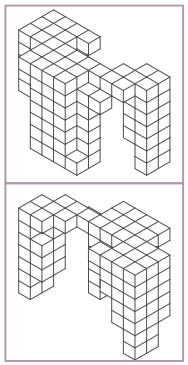
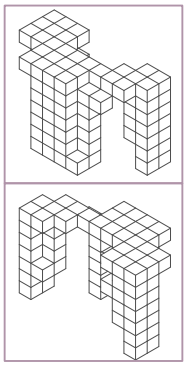
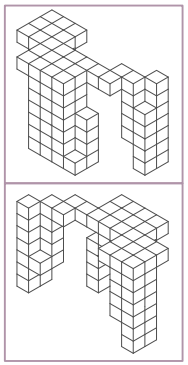
DEPTH FIRST SEARCH



List of Vertices
List of Vertices Visited

LOW - RESOLUTION ITERATIONS

HIGH - RESOLUTION ITERATIONS

CONCLUSION

Looping
Solid FEM
Optimization of the Code
Load Case

RESEARCH OBJECTIVE

The main objective is to develop a computational approach to optimize material uses of the construction materials -earth and bioplastics- in response to structural requirements.


STEP 1 : DECIDE SITE & MATERIALS


STEP 2 : INPUT SITE FOOTPRINT


STEP 3 : INPUT SITE HEIGHT LIMIT


STEP 4 : DETERMINE VOXEL SIZE


STEP 5 : DETERMINE SUPPORT AREA


STEP 6 : DETERMINE ROOF/CEILING

ZONING OF VOXELS

GROUND	SPACE	EXTERIOR WALL	MATERIAL	SLAB	ROOF	OPENING
self.index	self.index	self.index	self.index	self.index	self.index	self.index
self.vox	self.vox	self.vox	self.vox	self.vox	self.vox	self.vox
self.active	self.active	self.active	self.active	self.active	self.active	self.active
self.support	self.support	self.support	self.support	self.support	self.support	self.support
self.deadLoad	self.deadLoad	self.deadLoad	self.deadLoad	self.deadLoad	self.deadLoad	self.deadLoad
self.liveLoad	self.liveLoad	self.liveLoad	self.liveLoad	self.liveLoad	self.liveLoad	self.liveLoad
self.envLoad	self.envLoad	self.envLoad	self.envLoad	self.envLoad	self.envLoad	self.envLoad
self.center	self.center	self.center	self.center	self.center	self.center	self.center
self.adjacency	self.adjacency	self.adjacency	self.adjacency	self.adjacency	self.adjacency	self.adjacency
self.isCorner	self.isCorner	self.isCorner	self.isCorner	self.isCorner	self.isCorner	self.isEdge
self.Outside	self.Outside	self.Outside	self.Outside	self.Outside	self.Outside	self.isCorner
						self.Outside

TRUE
FALSE

MAIN FUNCTIONS

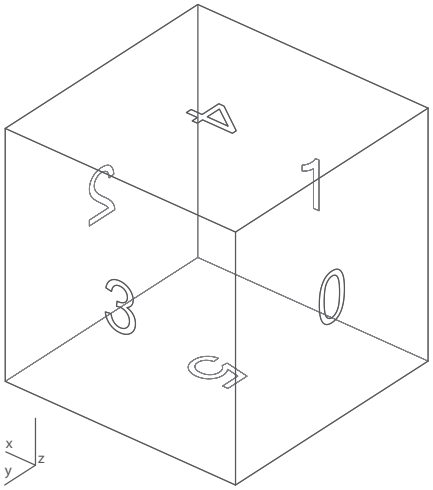
CARVING

Set self active to false
Set adjacent 4 voxels to ceiling
Set adjacent 5 voxels to slab
If Adjacent to Outside set Outside
If not Adjacent to Outside create ceiling

CHECK ROOF

If space on z+1 direction to ceiling
    add slab
Else set Roof

If Roof set load to Env Load
Elif slab set load to live load



CHECK LOAD

If Roof
    Add EnvLoad
Elif Slab
    Add LiveLoad

CHECK GROUND

If space on z-1 direction
    add slab
Else set Ground

MAIN INPUTS

Site Footprint
Height Restriction
Voxel Size
Slab Thickness
Live Loads
Environmental Loads
Material Properties
Stress Cases

VISUALIZATION SETTINGS

Voxel View

Stresses View

Post Optimized View

M. Manske, Human hip bone texture. Wikipedia Commons, 2008.