PHYLLOSTACHYS

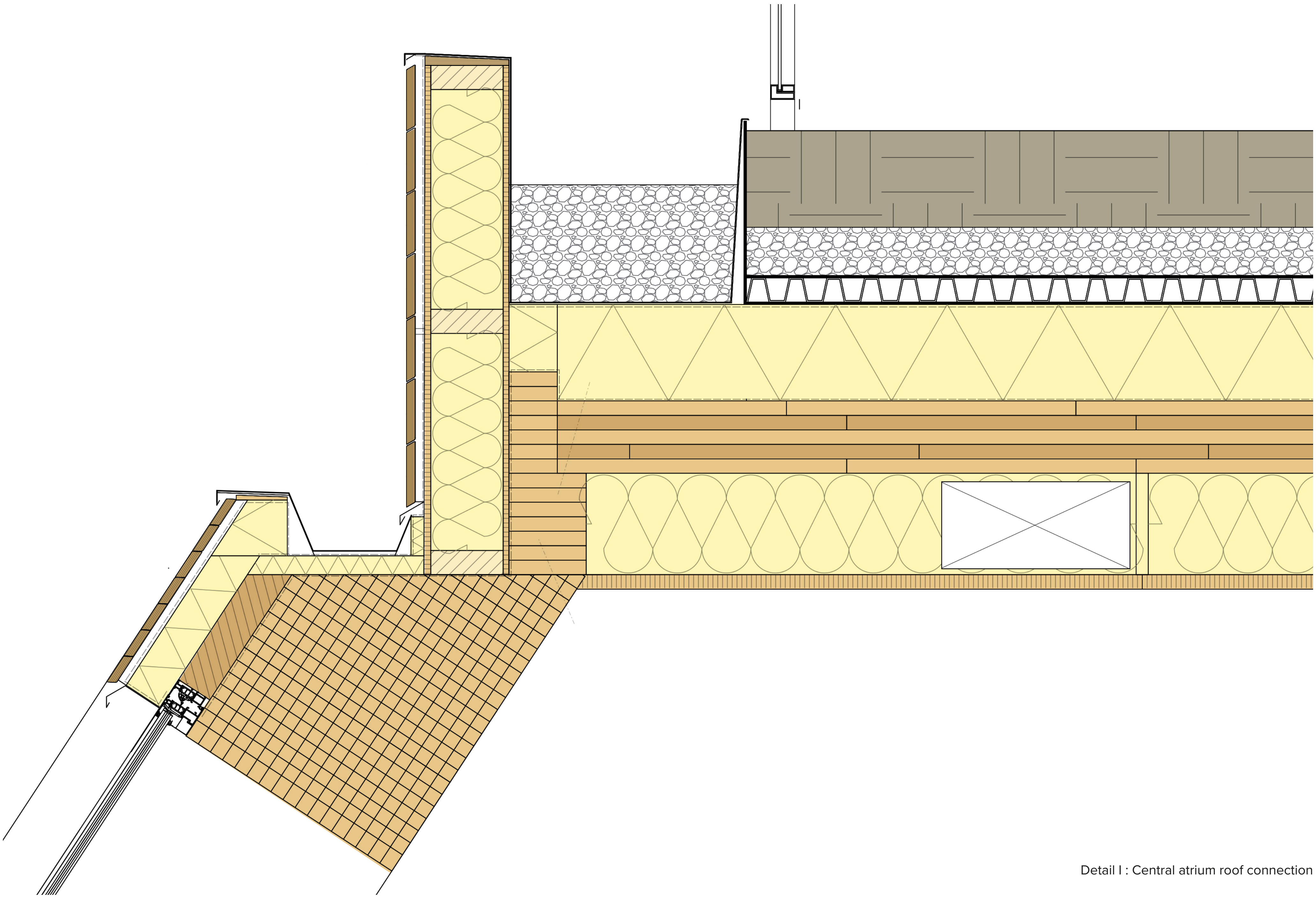
Additional Products

Luc Thomassen (4553136)

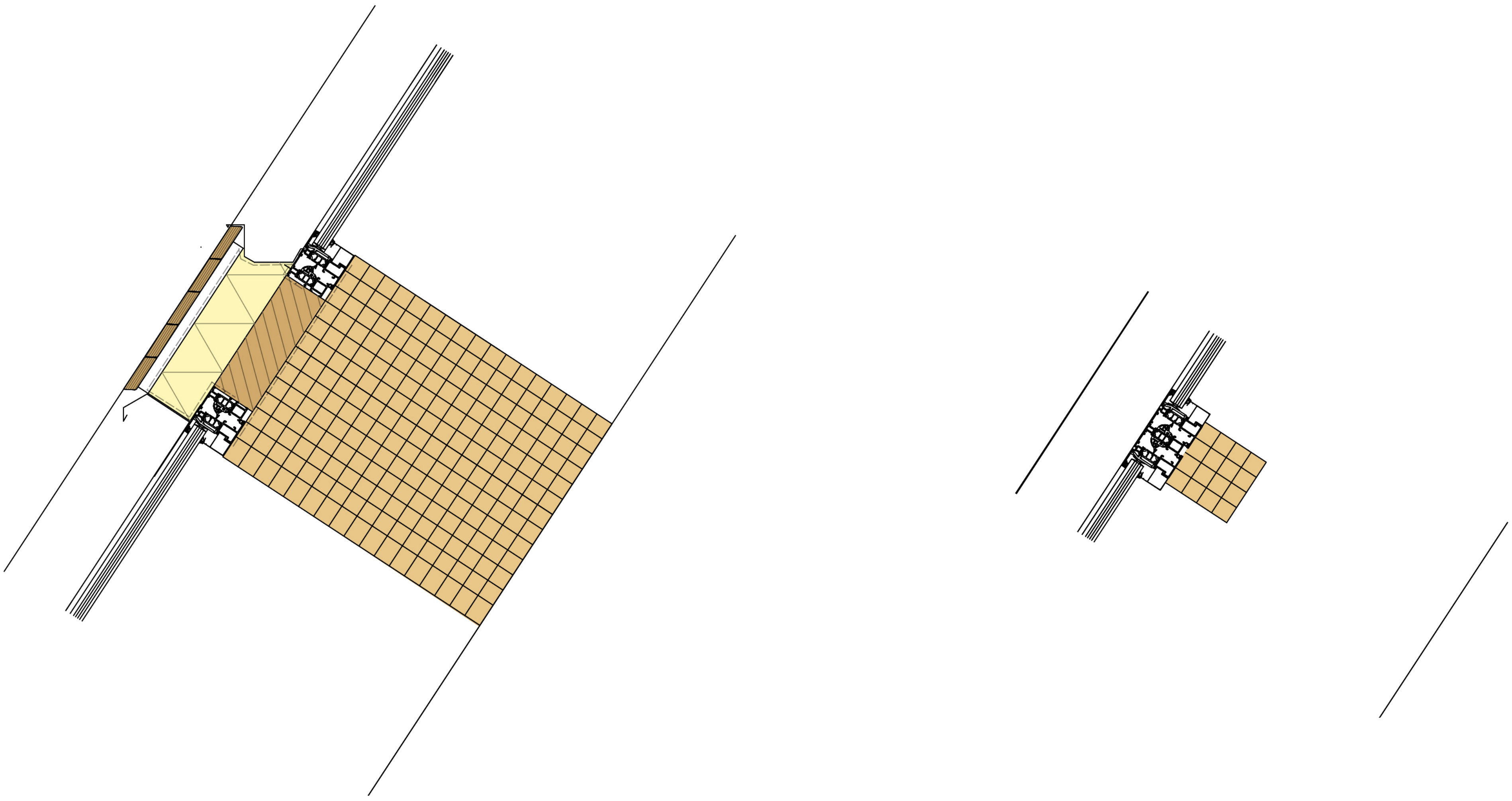
Contents

1. Additional Details

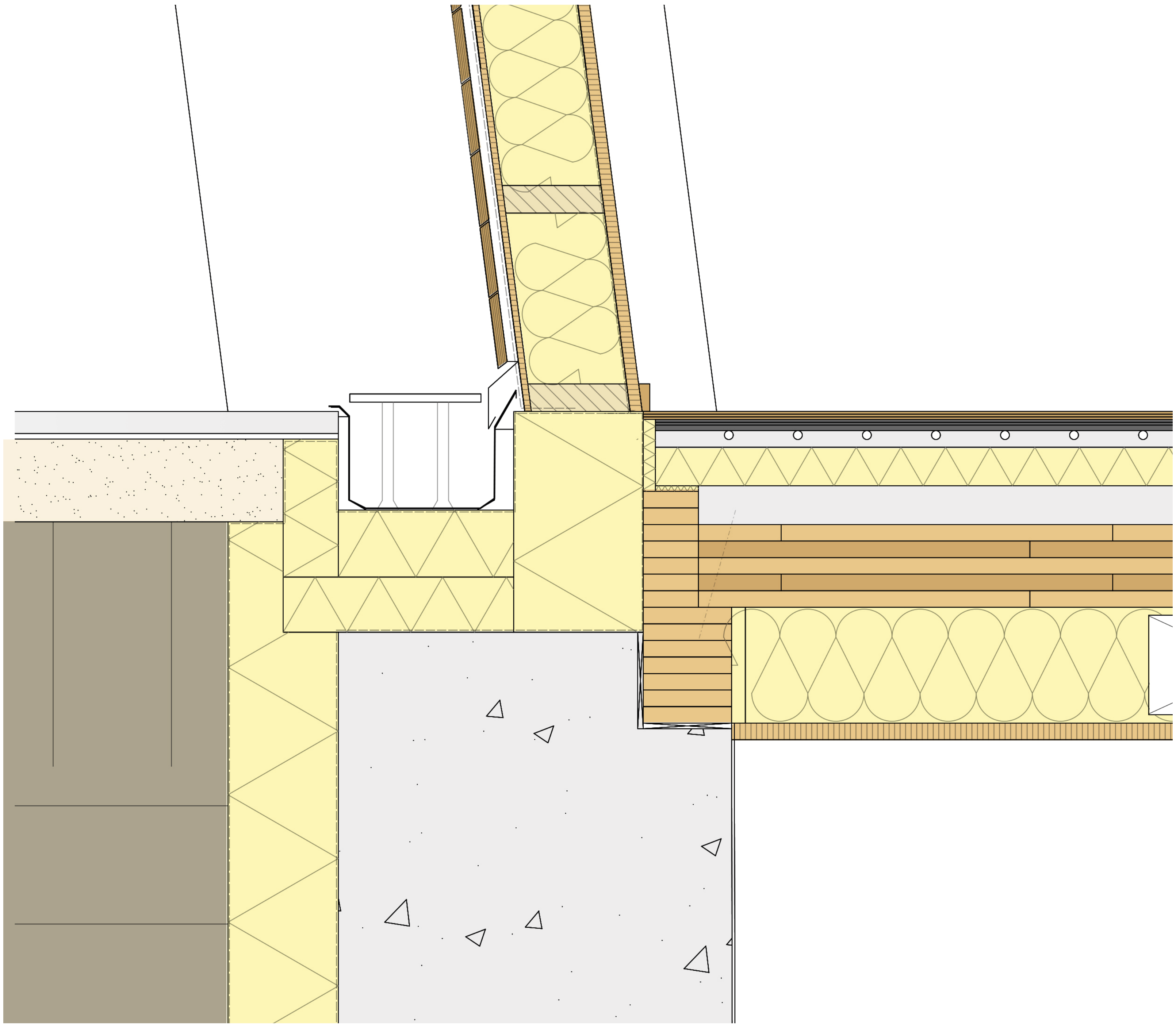
These are additional details that were not used on the poster or during the presentation, either because there was no physical space, or their principle is already explained in another detail.



Detail I : Central atrium roof connection



Detail J & K : BIPV Curtain wall connections



Detail L : Ground floor connection

2. Dimensioning Calculation (Bamboo variant)

The dimensioning of the main load bearing elements was calculated. The calculation is split up into five parts.

Loads
Firstly, the megastructure is split up into structural segments. For each of these segments, the floor- and facade areas are calculated, along with their associated weights in order to find the static load per segment. Along with the variable load per segment, the total UGT load per segment could now be established. The required safety correction factors were implemented and displayed in table 1.

Colums
Having established the total UGT load, the dimensioning calculation of the columns could be conducted. Firstly, the maximum amount of weight beared by one column was found and the associated normal foce through the column was calculated. Using the formula $\sigma = F / A$, the required section area could now be determined. Assuming a square column, the required thickness could also be determined. An overdimensioning layer was added to the minimal structural thickness to arrive at the minimum required thickness. In some cases, the minimum required thickness could also be the actual thickness, but in a number of cases, the actual thickness had to be more, with regards to joinery.
Lastly, insulation thickness was accounted for in the exoskeleton part of the megastructure.

Segment floor area *(m^2)*	**Segment facade area** *(m^2)*	**Package weight** *(m^2)*	**Static load per segment** *(kN)* 1,35x safety factor	**Variable load per segment** *(kN)* 2,5 kN/m^2 1,65x safety factor	**UGT load per segment** *(kN)*
1955,80	1338,35	**Floors**	10598,90	8067,68	18666,58
1955,80	1375,06	368,00 kg/m^2	10625,54	8067,68	18693,22
1848,14	1335,95	3,68 kN/m^2	10082,08	7623,58	17705,66
1758,60	1307,38		9696,88	7254,23	16951,11
1726,56	1269,40	**Facade**	9598,73	7122,06	16720,79
1753,74	1263,39	56,29 kg/m^2	9760,23	7234,18	16994,40
2128,92	1357,81	0,56 kN/m^2	11347,05	8781,80	20128,84
2981,92	1585,66		16741,38	12300,42	29041,80
4212,34	1901,43	**Combined**	23493,90	17375,90	40869,80
7674,57	3080,07	4,24 kN/m^2	42290,23	31657,60	73947,83

Table 1: Loads per structural segment (bamboo variant)

Heaviest load on column *(kN)*	**Part of segment weight beared**	**Required Section Area** *(mm^w)*	**Minimum strucutral thickness** *(mm)*	**Thickness after overdimensioning** *(mm)* 60 minute safety at 0,76mm/hr charring rate	**Minimum required thickness** *(mm)*	**Actual thickness** *(mm)*	**Insulated thickness** *(mm)*
Facade				0,76			
777,85	0,04	12346,88	111,12	202,32	201,00	300,00	540,00
1556,82	0,04	24711,38	157,20	248,40	249,00	300,00	540,00
2360,68	0,05	37471,06	193,57	239,17	240,00	300,00	540,00
3052,57	0,04	48453,43	220,12	311,32	312,00	320,00	561,00
3731,61	0,04	59231,93	243,38	334,58	336,00	335,00	576,00
4234,83	0,03	67219,55	259,27	350,47	351,00	350,00	591,00
4715,75	0,02	74853,16	273,59	364,79	366,00	375,00	615,00
5315,95	0,02	84380,14	290,48	381,68	381,00	390,00	630,00
6311,02	0,02	100174,91	316,50	407,70	408,00	405,00	645,00
7944,05	0,02	126096,01	355,10	446,30	447,00	450,00	690,00
Atrium (center)							
1866,66	0,10	29629,48	172,13	263,33	264,00		-
3735,98	0,10	59301,26	243,52	334,72	336,00		-
5665,06	0,11	89921,57	299,87	391,07	390,00		-
7325,61	0,10	116279,58	341,00	432,20	432,00		-
8883,19	0,09	141002,99	375,50	421,10	420,00		-
10143,93	0,07	161014,77	401,27	492,47	492,00		-
11246,11	0,05	178509,65	422,50	513,70	513,00		-
12478,45	0,04	198070,60	445,05	536,25	537,00		-
14137,12	0,04	224398,76	473,71	564,91	564,00		-
14637,93	0,01	232348,13	482,03	573,23	573,00		-
Atrium (side)							
622,19	0,03	9875,99	99,38	190,58	192,00		-
1245,26	0,03	19766,08	140,59	231,79	231,00		-
1888,29	0,04	29972,85	173,13	264,33	264,00		-
2441,84	0,03	38759,35	196,87	288,07	288,00		-
3230,90	0,05	51284,13	226,46	317,66	318,00		-
3992,41	0,04	63371,63	251,74	342,94	342,00		-
4850,90	0,04	76998,37	277,49	368,69	369,00		-
6128,81	0,04	97282,64	311,90	403,10	402,00		-
8179,49	0,05	129833,13	360,32	451,52	453,00		-
11234,29	0,04	178322,10	422,28	513,48	513,00		-

Table 2: Column dimensioning (bamboo variant)

Average segment floor area (m^2)	UGT load (kN/m2)	Total floor load (largest) (kN)	Largest floor area beared by beam (m^2)	Largest beam span (mm)	q load (N/mm)	Bending Moment (Nmm)	Bending strength (N/mm^2)	Required W (mm^3)	Required beam height (mm) 2:1 proportion; 60 minute safety at 0,76mm/hr charring rate	Required beam width (mm) 2:1 proportion; 60 minute safety at 0,76mm/hr charring rate	Real beam height (mm)	Real beam width (mm)	I (mm^4)	EI	$w_{additional}$ (mm)	$w_{allowed}$ (mm)	Minimum camber (mm)
488,95	9,54	388926,75	40,75	14678,00	26,50	713583350,07	99,00	7207912,63	443,01	267,51	450,00	250,00	1898437500,00	265781250000000,00	110,95	44,03	66,91
488,95	9,56	389481,85	40,75	14678,00	26,54	714601822,51	99,00	7218200,23	443,18	267,59	450,00	250,00	1898437500,00	265781250000000,00	110,95	44,03	66,91
462,04	9,58	378516,05	39,51	14717,00	25,72	696327591,32	99,00	7033612,03	440,16	266,08	450,00	250,00	1898437500,00	265781250000000,00	108,43	44,15	64,28
439,65	9,64	349509,36	36,26	13929,00	25,09	608539479,36	99,00	6146863,43	424,87	258,43	450,00	250,00	1898437500,00	265781250000000,00	84,39	41,79	42,60
431,64	9,68	329658,85	34,04	12496,00	26,38	514927127,30	99,00	5201284,11	360,84	226,42	450,00	250,00	1898437500,00	265781250000000,00	57,24	37,49	19,76
438,44	9,69	262706,13	27,11	12981,00	20,24	426273537,99	99,00	4305793,31	387,62	239,81	450,00	250,00	1898437500,00	265781250000000,00	51,09	38,94	12,15
532,23	9,45	274099,12	28,99	12372,00	22,15	423894292,41	99,00	4281760,53	387,07	239,53	450,00	250,00	1898437500,00	265781250000000,00	47,31	37,12	10,20
745,48	9,74	355971,30	36,55	13146,00	27,08	584949833,70	99,00	5908584,18	420,51	256,25	450,00	250,00	1898437500,00	265781250000000,00	71,54	39,44	32,10
1053,09	9,70	577292,72	59,50	18860,00	30,61	1360967577,86	99,00	13747147,25	527,30	309,65	550,00	300,00	4159375000,00	582312500000000,00	156,82	56,58	100,24
1279,10	12,39	731296,42	59,02	18048,00	40,52	1649804716,57	99,00	16664694,11	556,14	324,07	550,00	300,00	4159375000,00	582312500000000,00	136,41	54,14	82,27

Table 3: Beam dimensioning & camber (bamboo variant)

Beams

Having established the static and variable loads in earlier steps, the dimensioning of the beams could now also be calculated.

The UGT load per segment was determined and the heaviest loaded and largest spanning beam was found. This beam would be normative. Having established the q-load on this beam and its length, the resulting bending moment could be calculated using the formula $M = 1/8 \times q \times L^2$. As a result, the required section modulus could also be calculated using the formula $W = M / \sigma$. Assuming a 2:1 height/width proportion, the required height and width could now also be calculated using the formula $W = 1/6 \times w \times h^2$.

Camber

In order to determine required camber, I was calculated using the formula $I = 1/12 \times w \times h^3$. In combination with the known E-value of bamboo and the earlier established loads, the formula $(5 \times q \times L^4) / (384 \times EI)$ could be used to determine the additional sag. The allowed sag was calculated using the formula $0{,}003 \times L$. The minimum required camber could then be determined by subtracting the allowed sag from the additional sag.

Volume

Lastly, the volume of the megastructure and the insulation volume of the exoskeleton was determined, primarly to be used in the ECO-cost calculation. This volume was determined by combining the dimensioning established before with a BIM model.

Megastructure volume (m^3)	Exoskeleton insulation volume (m^3)
37,57	84,16
37,54	84,09
37,57	84,15
46,72	96,87
58,57	114,22
63,69	117,54
127,72	221,86
187,93	311,05
278,67	423,98
474,45	647,35
1,07	
1,58	
2,13	
2,63	
2,48	
3,55	
7,21	
8,54	
14,17	
20,83	
1,10	
1,52	
1,99	
2,37	
2,88	
3,38	
7,93	
9,46	
23,01	
66,62	
Total	**Total**
1534,89	2185,27

Table 4: Volume (bamboo variant)

3. Dimensioning Calculation (Steel & Concrete variant)

In order to accurately compare ECO-cost between the bamboo variant and the steel & concrete variant, some aspects of the megastructure had to be re-calculated in order to account for the higher strength of steel and lower strength of concrete, as well as the higher total weight of the construction.

Loads
Firstly, new packages were established using conversion values established in the design tool. As a result of this, the floor weight increased significantly. New UGT loads were therefore calculated in the same way as previously, but with a higher static load.

Columns
Secondly, the required section area of the colums was re-calculated in the same way as previously done, but accounting for steel's higher compressive strength. As a result, the megastructure's volume changed significantly.

Beams
The beams were not re-calculated for steel, because this would introduce a lot of complexity with regards to possible profile choices. Instead a conversion value from the thematic research paper was used to account for steel's lower volume.

Segment floor area *(m^2)*	**Segment facade area** *(m^2)*	**Package weight** *(m^2)*	**Static load per segment** *(kN)* 1,35x safety factor	**Variable load per segment** *(kN)* 2,5 kN/m² 1,65x safety factor	**UGT load per segment** *(kN)*
1955,80	1338,35	Floors	22709,32	8067,68	30776,99
1955,80	1375,06	850,00 kg/m²	22854,97	8067,68	30922,64
1848,14	1335,95	8,50 kN/m²	21760,00	7623,58	29383,57
1758,60	1307,38		20899,14	7254,23	28153,36
1726,56	1269,40	Facade	20721,15	7122,06	27843,21
1753,74	1263,39	56,29 kg/m²	21110,90	7234,18	28345,08
2128,92	1357,81	0,56 kN/m²	25572,79	8781,80	34354,59
2981,92	1585,66		36529,79	12300,42	48830,21
4212,34	1901,43	Combined	51897,78	17375,90	69273,68
7674,57	3080,07	9,06 kN/m²	94037,10	31657,60	125694,70

Table 5: Loads per structural segment (steel & concrete variant)

Heaviest load on column *(kN)*	**Max % of segment weight beared**	**Required Section Area** *(mm^w)*
Facade		
1282,51	0,04	3612,69
2571,08	0,04	7242,48
3905,13	0,05	11000,37
5054,26	0,04	14237,36
6185,00	0,04	17422,53
7024,32	0,03	19786,82
7845,12	0,02	22098,93
8854,28	0,02	24941,64
10540,91	0,02	29692,71
13316,69	0,02	37511,81
Atrium (center)		
3077,70	0,10	8669,58
6169,96	0,10	17380,18
9371,38	0,11	26398,26
12129,33	0,10	34167,12
14722,98	0,09	41473,17
16825,78	0,07	47396,55
18706,90	0,05	52695,50
20778,93	0,04	58532,19
23590,35	0,04	66451,70
24441,62	0,01	68849,63
Atrium (side)		
1025,85	0,03	2889,71
2056,55	0,03	5793,10
3123,69	0,04	8799,12
4043,06	0,03	11388,89
5356,99	0,05	15090,11
6627,12	0,04	18667,95
8092,33	0,04	22795,28
10240,97	0,04	28847,81
13716,84	0,05	38639,00
18909,33	0,04	53265,71

Table 6: Column dimensioning (steel & concrete variant)

Megastructure volume *(m^3)*	**Exoskeleton insulation volume** *(m^3)*
1,51	36,09
3,02	41,06
4,59	45,06
6,50	52,41
9,09	63,12
10,29	65,05
20,07	117,12
30,82	164,84
50,45	238,38
88,91	354,03
0,13	
0,24	
0,37	
0,48	
0,58	
0,69	
1,44	
1,73	
2,96	
4,38	
0,09	
0,17	
0,25	
0,33	
0,43	
0,54	
1,33	
1,69	
4,33	
13,69	
Total	**Total**
261,09	1177,16

Table 7: Volume (steel & concrete variant)

4. ECO-Cost Calculation

The basis for the ECO-cost calculation is the volume of material present and its total weight. Combined with the ECO-cost / kg figure defined for each material, this allows for a calculation of total ECO-cost per material.
The total volume of material was calculated using a BIM model. The packages as applied in the BIM model are defined in the tables below. The ECO-cost / kg figure was sourced from the thematic research and, for materials that were not part of that study, from the IDEMAT database (2020).

The calculation was performed for two scenarios. Firstly, the actual design with bamboo as the structural material (table 8). Secondly, a variant in which the structural elements were replaced with steel and concrete (table 9). It must be noted that the added weight and change in volume of the steel and concrete construction was accounted for. This is shown in the dimensioning calculations (tables 5-7)
The results of these calculations are shown in table 10 and visualized in the ECO-cost comparison on the poster.

	Layer thickness *(mm)*	**Density** *(kg/m3)*	**Weight in package** *(kg/m2)*	**ECO-cost / kg** *(€)*	**ECO-cost /m2** *(€)*	**Total Weight** *(kg)*	**Total ECO-cost** *(€)*
Floor (tower)							
Flattened bamboo	15,00	850,00	12,75	-0,09	-1,15	170082,45	-15307,42
Norit	20,00	1250,00	25,00	0,08	2,00	333495,00	26679,60
Heating	0,50	-				0,00	0,00
Wood Fibre	30,00	50,00	1,50	-0,15	-0,22	20009,70	-2901,41
Fermacell	70,00	90,00	6,30	0,08	0,50	84040,74	6723,26
Concrete (C30)	70,00	2100,00	129,36	0,03	3,28	1960950,60	43748,99
Glubam X-lam	150,00	880,00	116,16	-0,04	-4,65	1760853,60	-61982,05
Larch framing (2%)	230,00	350,00	1,42	-0,15	-0,21	21477,08	-2740,48
Mineral Wool (98%)	230,00	15,00	2,98	0,30	0,89	45101,86	11906,89
Flattened bamboo	30,00	850,00	25,50	-0,09	-2,30	340164,90	-30614,84
Glubam beams (12% of structural layer)	450,00	880,00	47,52	-0,04	-1,90	5282560,80	-25356,29
Floor (base)							
Flattened bamboo	15,00	850,00	12,75	-0,09	-1,15	381416,25	-34327,46
Norit	20,00	1250,00	25,00	0,08	2,00	747875,00	59830,00
Heating	0,50	-				0,00	0,00
Wood Fibre	30,00	50,00	1,50	-0,15	-0,22	44872,50	-6506,51
Fermacell	70,00	90,00	6,30	0,08	0,50	188464,50	15077,16
Concrete (C30)	70,00	2100,00	129,36	0,03	3,28	4397505,00	98108,76
Glubam X-lam	150,00	880,00	116,16	-0,04	-4,65	3948780,00	-138997,06
Larch framing (2%)	330,00	350,00	2,03	-0,15	-0,29	69103,65	-8817,63
Mineral Wool (98%)	330,00	15,00	4,27	0,30	1,28	145117,67	38311,06
Flattened bamboo	30,00	850,00	25,50	-0,09	-2,30	762832,50	-68654,93
Glubam beams (12% of structural layer)	550,00	880,00	58,08	-0,04	-2,32	14478860,00	-69498,53
Floor (basement)							
Reinforced Concrete (C30)	500,00	2400,00	1056,00	0,04	39,07	4104000,00	133611,19
Expanded Cork	200,00	105,00	18,48	0,29	5,36	71820,00	18328,46
Floor (balcony & roof)							
Expanded Cork	180,00	105,00	18,90	0,29	5,48	28013,58	8123,94
Glubam X-lam	150,00	880,00	116,16	-0,04	-4,65	195650,40	-6886,89
Expanded Cork	180,00	105,00	18,90	0,29	5,48	28013,58	8123,94
Glubam beams (12% of structural layer)	450,00	880,00	47,52	-0,04	-1,90	586951,20	-2817,37
Facade (closed)							
MDF	22,00	650,00	14,30	-0,56	-7,94	102029,07	-56626,13
Mineral Wool (80%)	180,00	15,00	2,16	0,30	0,65	19264,23	4623,42
Larch framing (20% of facade layer)	180,00	350,00	12,60	-0,15	-1,83	449498,70	-13035,46
MDF	12,00	650,00	7,80	-0,56	-4,33	55652,22	-30886,98
Larch framing (5%)	20,00	350,00	0,35	-0,15	-0,05	49944,30	-362,10
Strand Woven Bamboo (hot pressed)	18,00	1150,00	20,70	0,00	0,00	147692,43	0,00
Facade (window)							
Glass (HR+++ safety)	-		33,20	0,23	7,64	665924,00	127124,89
Flattened bamboo (12%)	200,00	850,00	20,40	-0,09	-1,84	2830177,00	-30565,91
Aluminium (5% & 10% infill)	150,00	2712,00	2,03	3,16	6,43	6772447,08	107004,66
Wall (foundation)							
Reinforced Concrete (C30)	700,00	2400,00	1478,40	0,04	54,69	3039120,00	98942,60
Expanded Cork	200,00	105,00	18,48	0,29	5,36	37989,00	9694,79
Wall (inside main)							
Plybamboo	12,00	700,00	8,40	-0,01	-0,08	150390,17	-1503,90
Mineral wool (90%)	240,00	15,00	2,88	0,30	0,86	64452,93	15468,70
Larch Rachel (10% of facade layer)	240,00	350,00	16,80	-0,15	-2,44	1503901,73	-43613,15
MDF	12,00	650,00	7,80	-0,56	-4,33	139648,02	-77504,65
MDF	12,00	650,00	7,80	-0,56	-4,33	139648,02	-77504,65
Mineral wool (90%)	240,00	15,00	2,88	0,30	0,86	64452,93	15468,70
Larch Rachel (10% of facade layer)	240,00	350,00	16,80	-0,15	-2,44	1503901,73	-43613,15
Plybamboo	12,00	700,00	8,40	-0,01	-0,08	150390,17	-1503,90
Megastructure							
Plybamboo LBL	-	700,00	-	-0,01	-	-	-10744,24
Expanded Cork	-	105,00	-	0,29	-	-	66541,42
Strand Woven Bamboo (hot pressed)	-	1150,00	-	0,00	-	-	0,00
Steel (S355)	-	7850,00	-	0,68	-	-	166530,00

Table 8: Package definition and resulting ECO-cost for bamboo variant

	Layer thickness *(mm)*	Density *(kg/m3)*	Weight in package *(kg/m2)*	ECO-cost / kg *(€)*	ECO-cost /m2 *(€)*	Total Weight *(kg)*	Total ECO-cost *(€)*
Flattened bamboo	15,00	850,00	12,75	-0,09	-1,15	551498,70	-49634,88
Norit	20,00	1250,00	25,00	0,08	2,00	1081370,00	86509,60
Heating	0,50	-	-	-	-	0,00	0,00
Wood Fibre	30,00	50,00	1,50	-0,15	-0,22	64882,20	-9407,92
Fermacell	70,00	90,00	6,30	0,08	0,50	272505,24	21800,42
Reinforced Concrete (C30)	275,00	2400,00	633,60	0,04	23,44	28548168,00	1013916,73
Larch Framing (2%)	230,00	350,00	1,42	-0,15	-0,21	69640,23	-8886,09
Mineral Wool (98%)	230,00	15,00	2,98	0,30	0,89	146244,48	38608,54
Flattened bamboo	30,00	850,00	25,50	-0,09	-2,30	1102997,40	-99269,77
Steel beams (4% of structural layer)	450,00	7850,00	141,30	0,68	96,08	152797581,00	4156094,20
Floor (basement)							
Reinforced Concrete (C30)	500,00	2400,00	1056,00	0,04	39,07	4104000,00	133611,19
Expanded Cork	200,00	105,00	18,48	0,29	5,36	71820,00	18328,46
Floor (balcony & roof)							
Expanded Cork	180,00	105,00	18,90	0,29	5,48	28013,58	8123,94
Reinforced Concrete (C30)	275,00	2400,00	633,60	0,04	23,44	978252,00	34743,60
Expanded Cork	180,00	105,00	18,90	0,29	5,48	28013,58	8123,94
Steel beams (4% of structural layer)	450,00	7850,00	141,30	0,68	96,08	5235871,50	142415,70
Facade (closed)							
MDF	22,00	650,00	14,30	-0,56	-7,94	102029,07	-56626,13
Mineral Wool (80%)	180,00	15,00	2,16	0,30	0,65	19264,23	4623,42
Larch framing (20% of facade layer)	180,00	350,00	12,60	-0,15	-1,83	449498,70	-13035,46
MDF	12,00	650,00	7,80	-0,56	-4,33	55652,22	-30886,98
Larch framing (5%)	20,00	350,00	0,35	-0,15	-0,05	49944,30	-362,10
Strand Woven Bamboo (hot pressed)	18,00	1150,00	20,70	0,00	0,00	147692,43	0,00
Facade (window)							
Glass (HR+++ safety)	-		33,20	0,23	7,64	665924,00	127124,89
Flattened bamboo (12%)	200,00	850,00	20,40	-0,09	-1,84	2830177,00	-30565,91
Aluminium (5% & 10% infill)	150,00	2712,00	2,03	3,16	6,43	6772447,08	107004,66
Wall (foundation)							
Reinforced Concrete (C30)	700,00	2400,00	1478,40	0,04	54,69	3039120,00	98942,60
Expanded Cork	200,00	105,00	18,48	0,29	5,36	37989,00	9694,79
Wall (inside main)							
Plybamboo	12,00	700,00	8,40	-0,01	-0,08	150390,17	-1503,90
Mineral wool (90%)	240,00	15,00	2,88	0,30	0,86	64452,93	15468,70
Larch Rachel (10% of facade layer)	240,00	350,00	16,80	-0,15	-2,44	1503901,73	-43613,15
MDF	12,00	650,00	7,80	-0,56	-4,33	139648,02	-77504,65
MDF	12,00	650,00	7,80	-0,56	-4,33	139648,02	-77504,65
Mineral wool (90%)	240,00	15,00	2,88	0,30	0,86	64452,93	15468,70
Larch Rachel (10% of facade layer)	240,00	350,00	16,80	-0,15	-2,44	1503901,73	-43613,15
Plybamboo	12,00	700,00	8,40	-0,01	-0,08	150390,17	-1503,90
Megastructure							
Steel (S355)	-	7850,00	-	0,68	-	-	1393719,16
Expanded Cork	-	105,00	-	0,29	-	-	35844,61
Strand Woven Bamboo (hot pressed)	-	1150,00	-	0,00	-	-	0,00

Table 9: Package definition and resulting ECO-cost for steel & concrete variant

	Total ECO-cost of building *(€)* Engineered bamboo variant	Total ECO-cost of building *(€)* Steel & concrete variant
Flattened bamboo	-179470,56	-80200,79
Plybamboo	-13752,04	-3007,80
Glubam	-305538,18	0,00
Strand woven bamboo (hot pressed)	0,00	0,00
Larch (sawn)	-112181,96	-109509,95
MDF	-242522,42	-242522,42
Concrete (C30)	141857,75	0,00
Reinforced concrete (C30)	232553,80	1281214,13
Steel (S355)	166530,00	5692229,07
Aluminium	107004,66	107004,66
Glass (HR+++ Safety)	127124,89	127124,89
Expanded Cork	110812,56	80115,75
Mineral Wool	85778,78	74169,36
Recycled Wood fibre	-9407,92	-9407,92
Norit	86509,60	86509,60
Fermacell	21800,42	21800,42
Subtotal	217099,37	7025519,00

Table 10: ECO-cost comparison

5. Climate Information

The data used for the solar panel yield and rainwater collection yield is shown in the tables below.

For the solar panel calculation, the roof / facade area used for energy production, along with their orientation was taken from a BIM model. This, combined with yield data from manufacturers and climate data from Volta Solar (n.d.) allowed for a calculated estimate of total energy production.

For the rainwater collection calculation, the total roof / balcony area used for collection was taken from a BIM model. Along with the amount of inhabitants and data on water usage from the KNMI Klimaatatlas (n.d.), this allowed for a calculated estimate of total water consumption by inhabitants and total water collection. This then allowed for a calculated estimate on how many toilet flushes could be accounted for using rainwater.

Area *(m^2)*	**Oriëntation & yield**
306,41	S 15° High yield panels (24%)
587	SSE & SSW 36° BIPV pannels (4%)
370	S 36° High yield panels (24%)
1157,8	S 30° BIPV panels (4%)

Table 11: Solar orientation & yield

Solar information retrieved from:
Volta solar. (n.d.). Opbrengst Tabel VoltaSolar [Table]. https://voltasolar.nl/wp-content/uploads/Opbrengst_Tabel_VoltaSolar.pdf

Apartments	123
Average inhabitants	307,5
Liters flushed / year *(L)*	3928313
Roof & balcony area *(m2)*	3381
Rainwater caught *(L)*	2873850
Amount of flushes accounted for *(%)*	73

Table 12: Rainwater yield

Rainwater information retrieved from:
Klimaatatlas | Zuid-Holland. (n.d.). KNMI. Retrieved October 28, 2021, from https://zuid-holland.klimaatatlas.net/