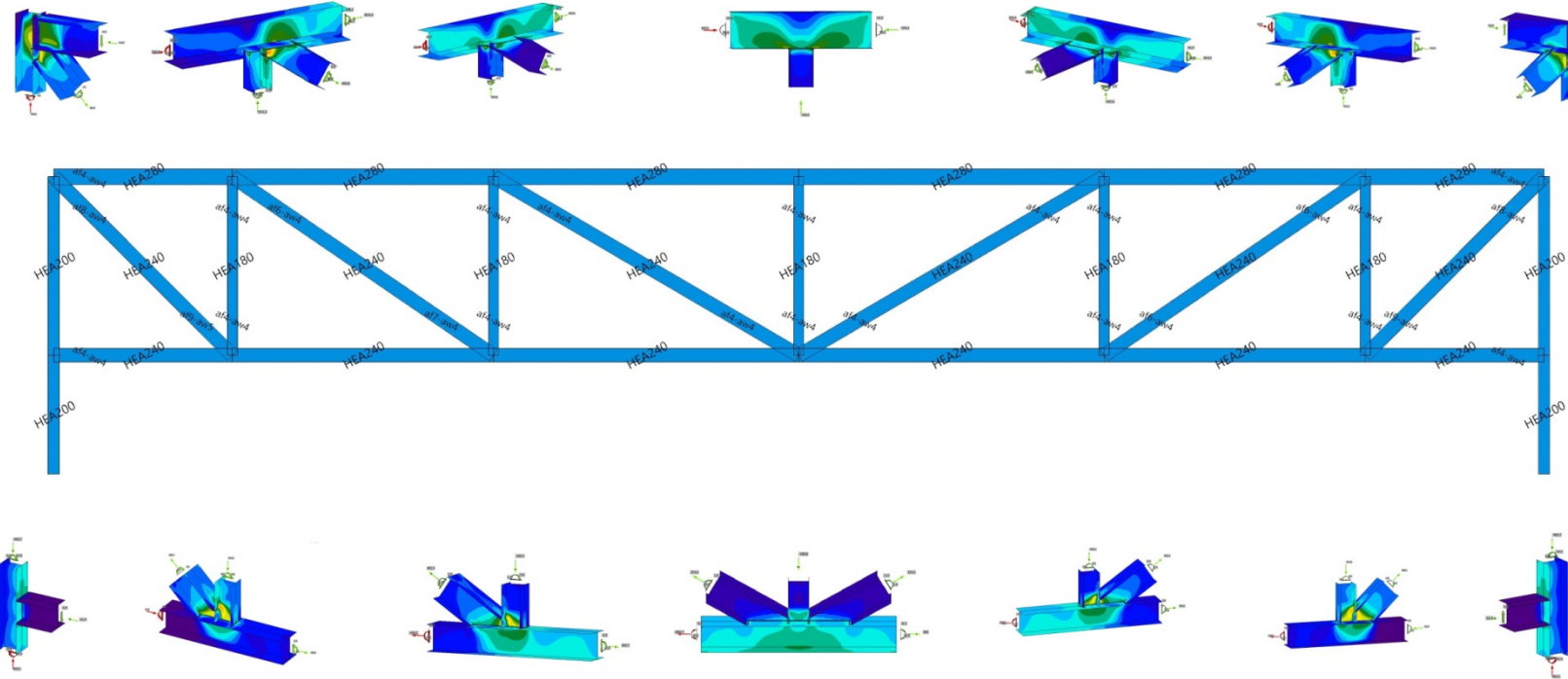
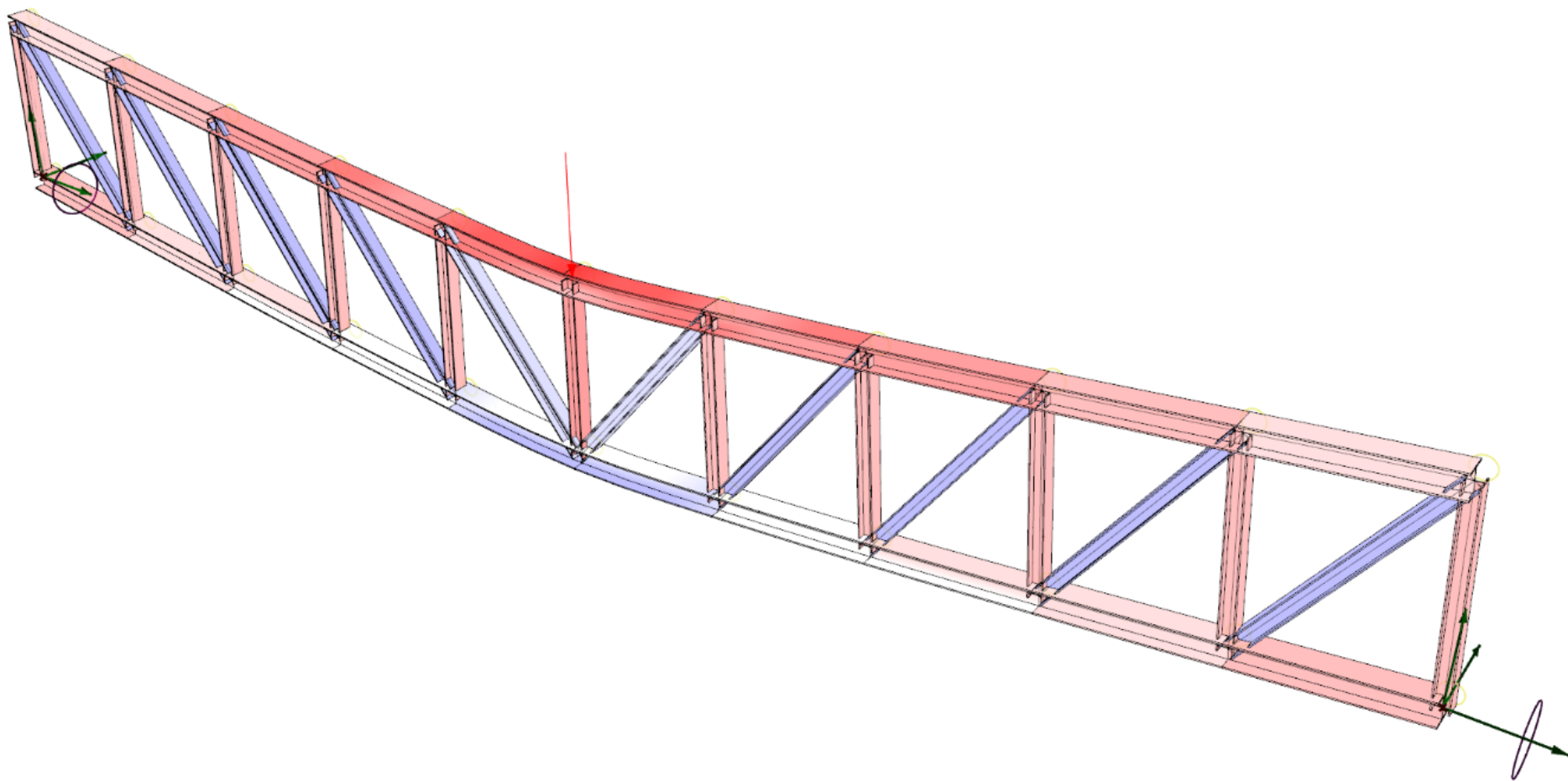


# Vakwerk van de toekomst



Rayaan Ajouz  
ABT bv TU Delft





# Constructeur en Staalbouwer

**Constructeur**



**Staalbouwer**



---

**Kerntaak**

Hoofd-draagconstructie

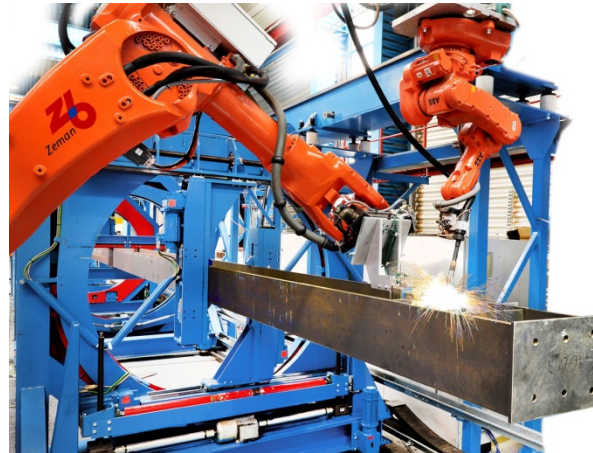
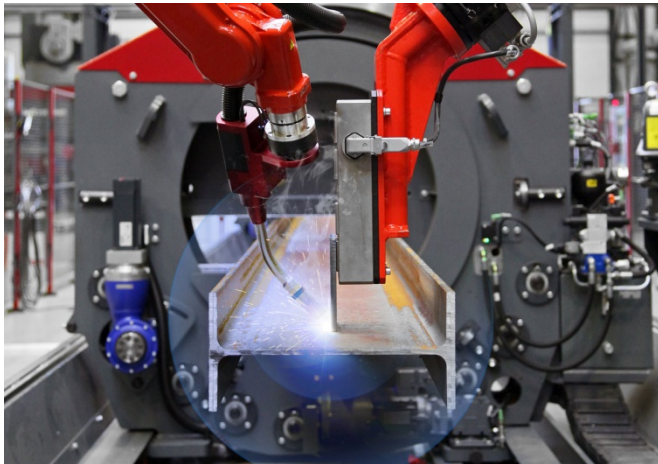
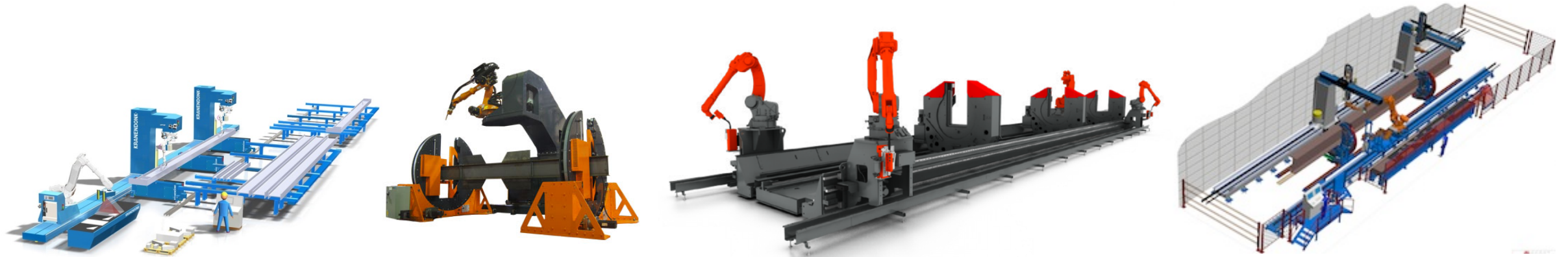
Detail-engineering

---



# Industry 4.0

Geautomatiseerd assembleren en lassen



# Huidige methodiek

Engineering



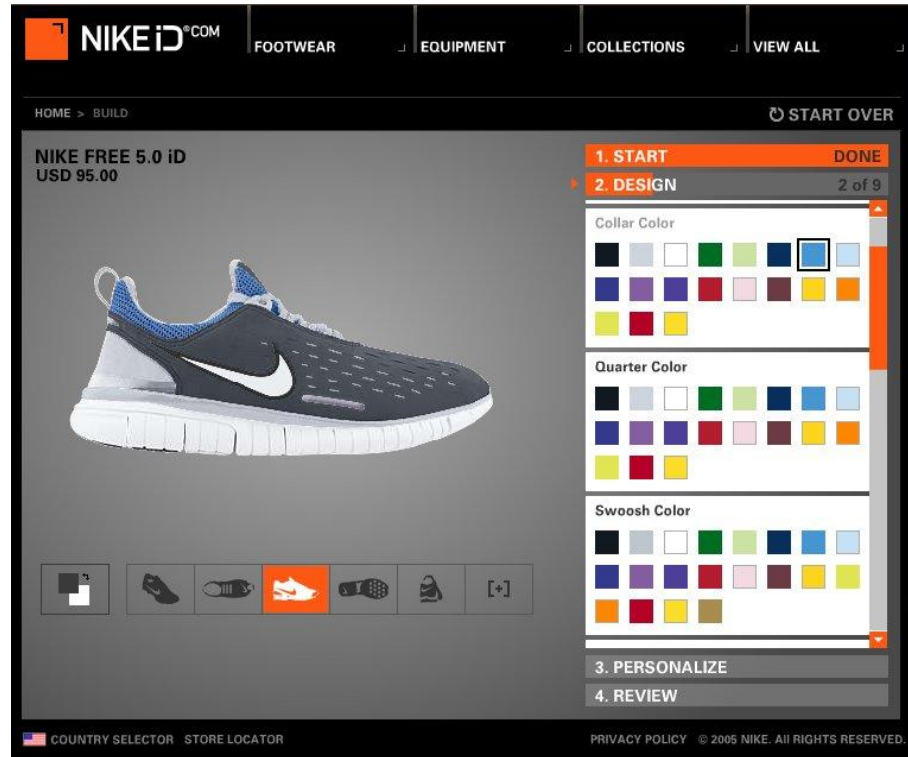
Productie



Inspectie

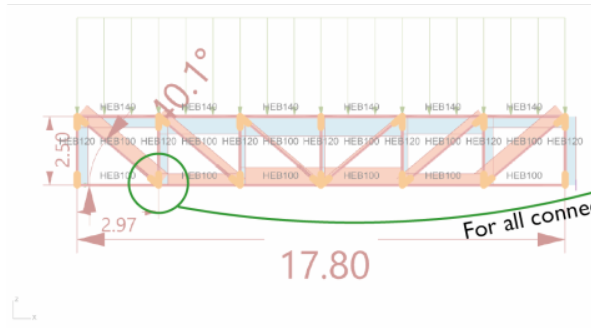


# Mass-customization

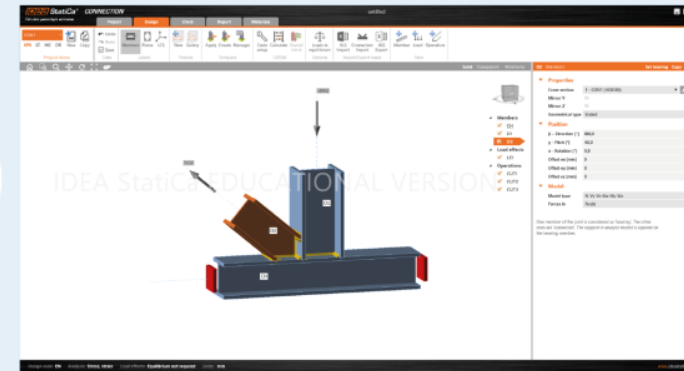


# Optimalisatie tool vakwerken





Var: Template  
Var: Geometry  
Var: Sections  
Var: Forces



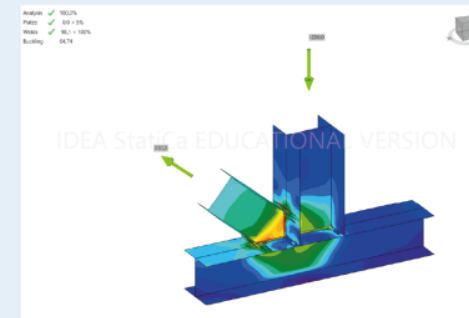
### Calculate

Update model

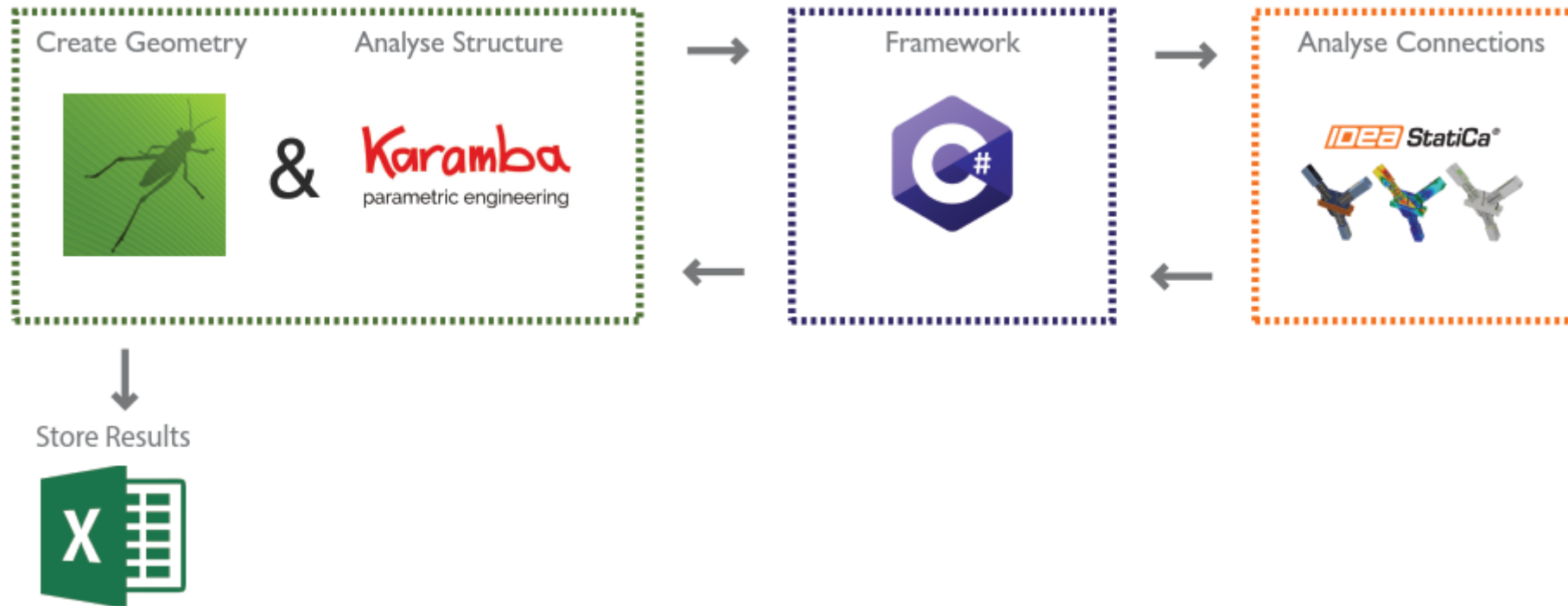
## Results

- required weld throat thicknesses
- strain of plates

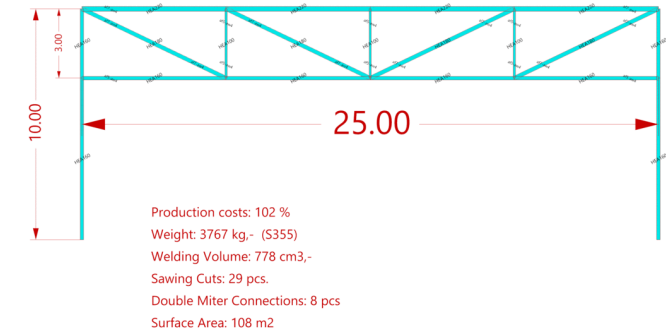
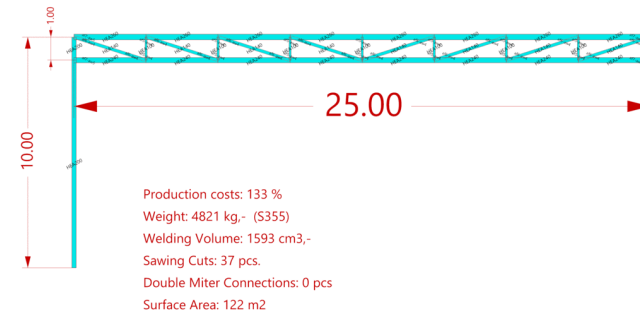
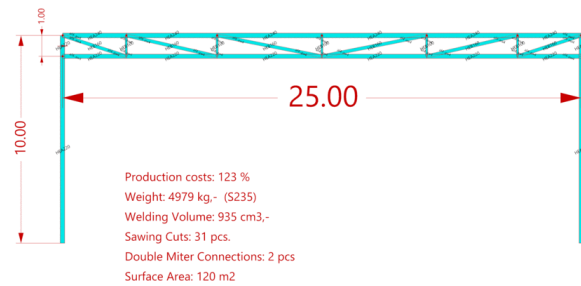
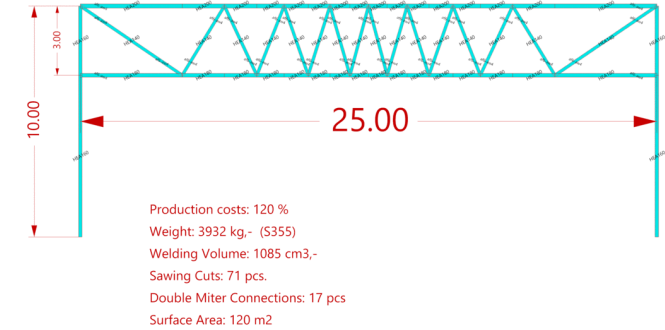
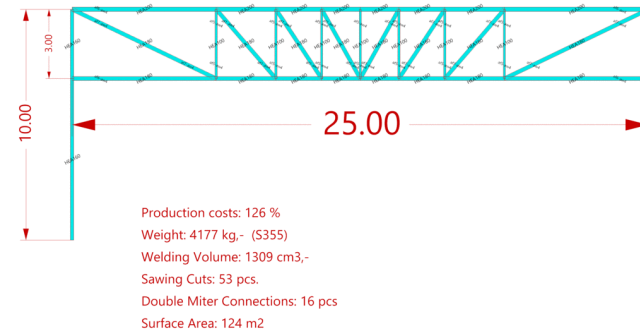
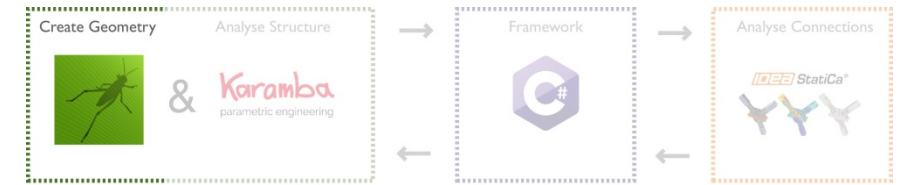
Source		Target		Flow		Substation	
Table of available for common load (after (buses) substation)							
X	Y	Source	Target	TS (kV)	Line	Length (km)	Loss (%)
1	2	10	11	10	10	10	10
1	3	10	12	10	10	10	10
1	4	10	13	10	10	10	10
1	5	10	14	10	10	10	10
1	6	10	15	10	10	10	10
1	7	10	16	10	10	10	10
1	8	10	17	10	10	10	10
1	9	10	18	10	10	10	10
1	10	10	19	10	10	10	10
1	11	10	20	10	10	10	10
1	12	10	21	10	10	10	10
1	13	10	22	10	10	10	10
1	14	10	23	10	10	10	10
1	15	10	24	10	10	10	10
1	16	10	25	10	10	10	10
1	17	10	26	10	10	10	10
1	18	10	27	10	10	10	10
1	19	10	28	10	10	10	10
1	20	10	29	10	10	10	10
1	21	10	30	10	10	10	10
1	22	10	31	10	10	10	10
1	23	10	32	10	10	10	10
1	24	10	33	10	10	10	10
1	25	10	34	10	10	10	10
1	26	10	35	10	10	10	10
1	27	10	36	10	10	10	10
1	28	10	37	10	10	10	10
1	29	10	38	10	10	10	10
1	30	10	39	10	10	10	10
1	31	10	40	10	10	10	10
1	32	10	41	10	10	10	10
1	33	10	42	10	10	10	10
1	34	10	43	10	10	10	10
1	35	10	44	10	10	10	10
1	36	10	45	10	10	10	10
1	37	10	46	10	10	10	10
1	38	10	47	10	10	10	10
1	39	10	48	10	10	10	10
1	40	10	49	10	10	10	10
1	41	10	50	10	10	10	10
1	42	10	51	10	10	10	10
1	43	10	52	10	10	10	10
1	44	10	53	10	10	10	10
1	45	10	54	10	10	10	10
1	46	10	55	10	10	10	10
1	47	10	56	10	10	10	10
1	48	10	57	10	10	10	10
1	49	10	58	10	10	10	10
1	50	10	59	10	10	10	10
1	51	10	60	10	10	10	10
1	52	10	61	10	10	10	10
1	53	10	62	10	10	10	10
1	54	10	63	10	10	10	10
1	55	10	64	10	10	10	10
1	56	10	65	10	10	10	10
1	57	10	66	10	10	10	10
1	58	10	67	10	10	10	10
1	59	10	68	10	10	10	10
1	60	10	69	10	10	10	10
1	61	10	70	10	10	10	10
1	62	10	71	10	10	10	10
1	63	10	72	10	10	10	10
1	64	10	73	10	10	10	10
1	65	10	74	10	10	10	10
1	66	10	75	10	10	10	10
1	67	10	76	10	10	10	10
1	68	10	77	10	10	10	10
1	69	10	78	10	10	10	10
1	70	10	79	10	10	10	10
1	71	10	80	10	10	10	10
1	72	10	81	10	10	10	10
1	73	10	82	10	10	10	10
1	74	10	83	10	10	10	10
1	75	10	84	10	10	10	10
1	76	10	85	10	10	10	10
1	77	10	86	10	10	10	10
1	78	10	87	10	10	10	10
1	79	10	88	10	10	10	10
1	80	10	89	10	10	10	10
1	81	10	90	10	10	10	10
1	82	10	91	10	10	10	10
1	83	10	92	10	10	10	10
1	84	10	93	10	10	10	10
1	85	10	94	10	10	10	10
1	86	10	95	10	10	10	10
1	87	10	96	10	10	10	10
1	88	10	97	10	10	10	10
1	89	10	98	10	10	10	10
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1	91	10	100	10	10	10	10
1	92	10	101	10	10	10	10
1	93	10	102	10	10	10	10
1	94	10	103	10	10	10	10
1	95	10	104	10	10	10	10
1	96	10	105	10	10	10	10
1	97	10	106	10	10	10	10
1	98	10	107	10	10	10	10
1	99	10	108	10	10	10	10
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1	101	10	110	10	10	10	10
1	102	10	111	10	10	10	10
1	103	10	112	10	10	10	10
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1	106	10	115	10	10	10	10
1	107	10	116	10	10	10	10
1	108	10	117	10	10	10	10
1	109	10	118	10	10	10	10
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1	112	10	121	10	10	10	10
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1	115	10	124	10	10	10	10
1	116	10	125	10	10	10	10
1	117	10	126	10	10	10	10
1	118	10	127	10	10	10	10
1	119	10	128	10	10	10	10
1	120	10	129	10	10	10	10
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1	122	10	131	10	10	10	10
1	123	10	132	10	10	10	10
1	124	10	133	10	10	10	10
1	125	10	134	10	10	10	10
1	126	10	135	10	10	10	10
1	127	10	136	10	10	10	10
1	128	10	137	10	10	10	10
1	129	10	138	10	10	10	10
1	130	10	139	10	10	10	10
1	131	10	140	10	10	10	10
1	132	10	141	10	10	10	10
1	133	10	142	10	10	10	10
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1	137	10	146	10	10	10	10
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1	142	10	151	10	10	10	10
1	143	10	152	10	10	10	10
1	144	10	153	10	10	10	10
1	145	10	154	10	10	10	10
1	146	10	155	10	10	10	10
1	147	10	156	10	10	10	10
1	148	10	157	10	10	10	10
1	149	10	158	10	10	10	10
1	150	10	159	10	10	10	10
1	151	10	160	10	10	10	10
1	152	10	161	10	10	10	10
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1	154	10	163	10	10	10	10
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1	157	10	166	10	10	10	10
1	158	10	167	10	10	10	10
1	159	10	168	10	10	10	10
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1	161	10	170	10	10	10	10
1	162	10	171	10	10	10	10
1	163	10	172	10	10	10	10
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1	169	10	178	10	10	10	10
1	170	10	179	10	10	10	10
1	171	10	180	10	10	10	10
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1	173	10	182	10	10	10	10
1	174	10	183	10	10	10	10
1	175	10	184	10	10	10	10
1	176	10	185	10	10	10	10
1	177	10	186	10	10	10	10
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1	183	10	192	10	10	10	10
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1	188	10	197	10	10	10	10
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1	190	10	199	10	10	10	10
1	191	10	200	10	10	10	10
1	192	10	201	10	10	10	10
1	193	10	202	10	10	10	10
1	194	10	203	10	10	10	10
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1	201	10	210	10	10	10	10
1	202	10	211	10	10	10	10
1	203	10	212	10	10	10	10
1	204	10	213	10	10	10	10
1	205	10	214	10	10	10	10
1							



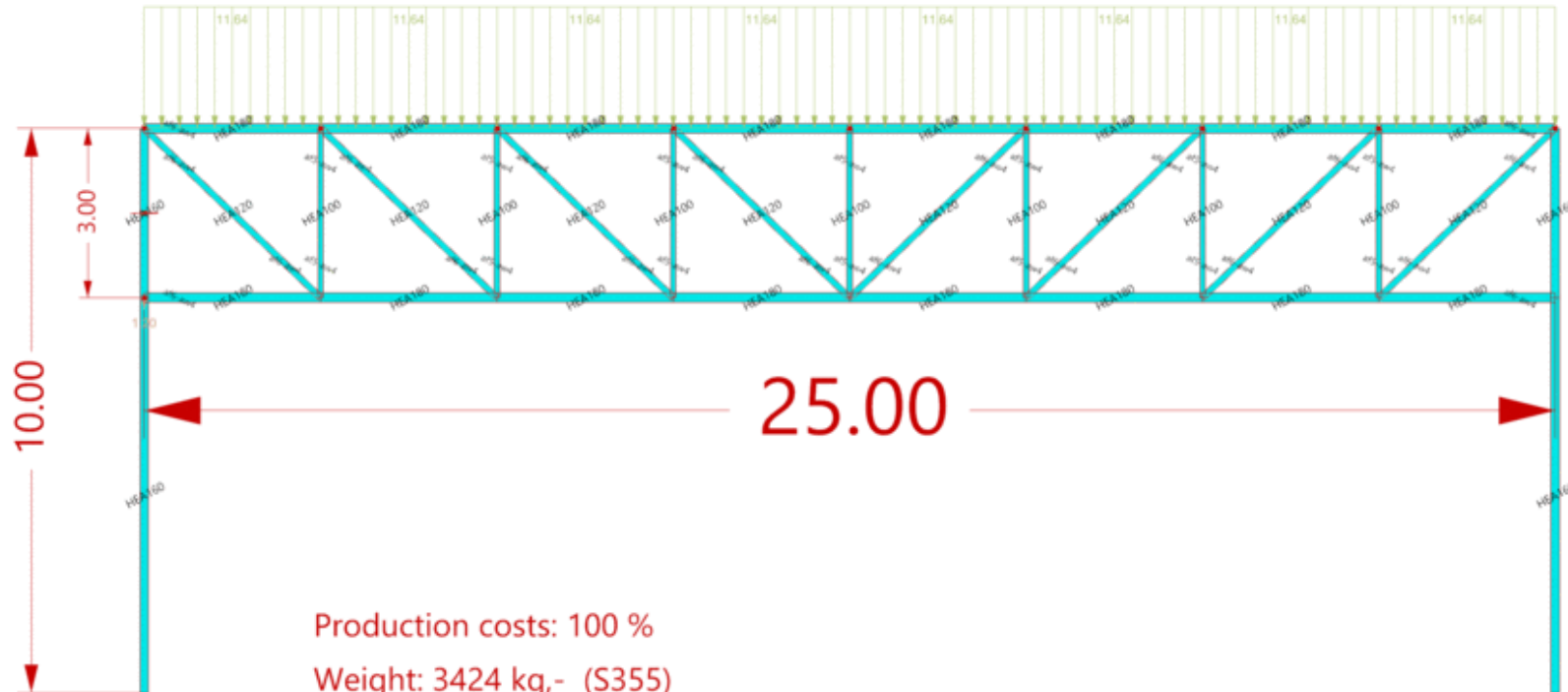
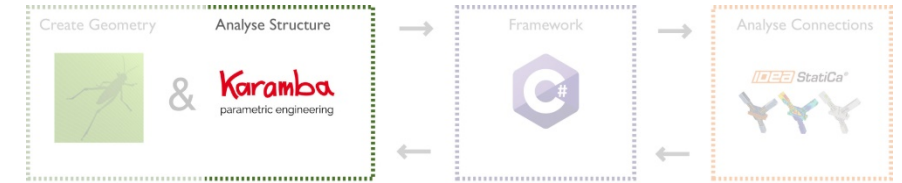
# Koppeling tussen programma's



# Geometrie



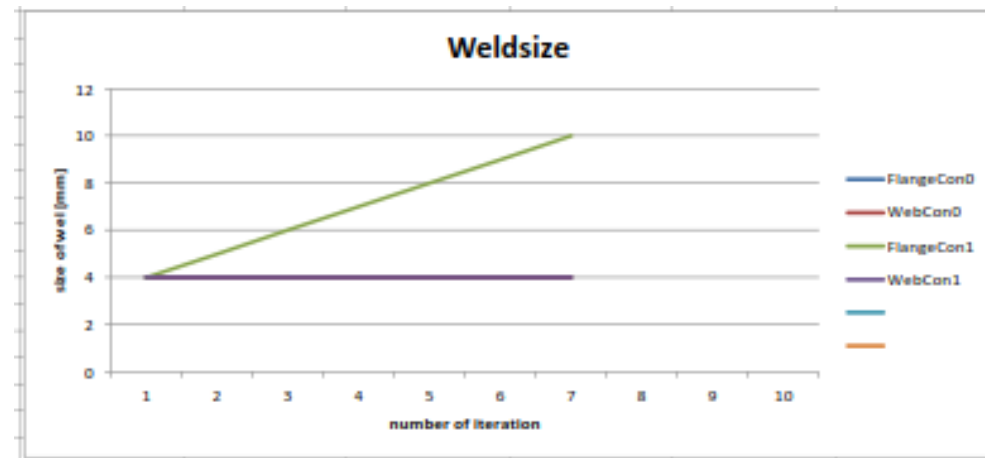
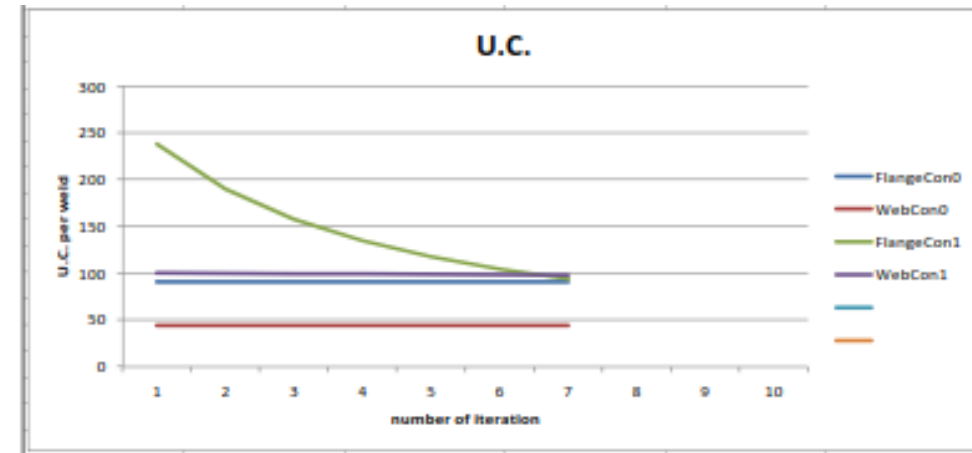
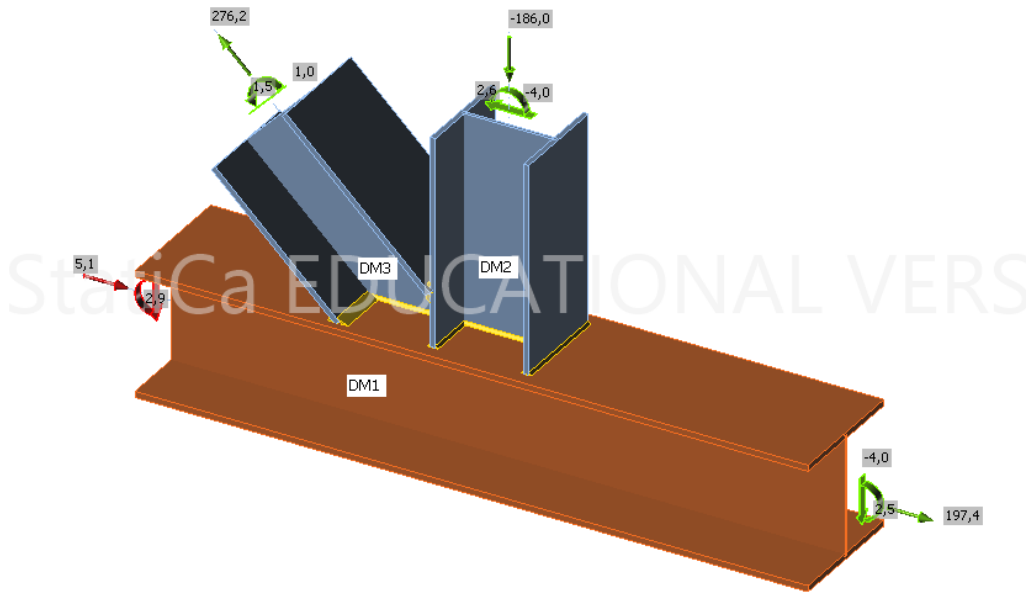
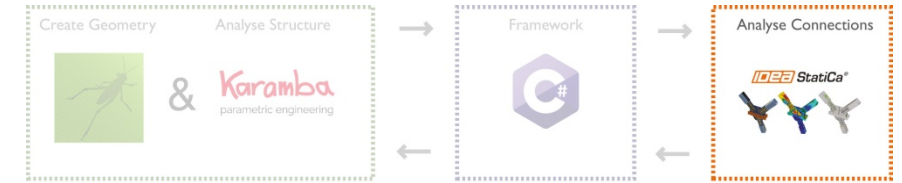
# Size optimization



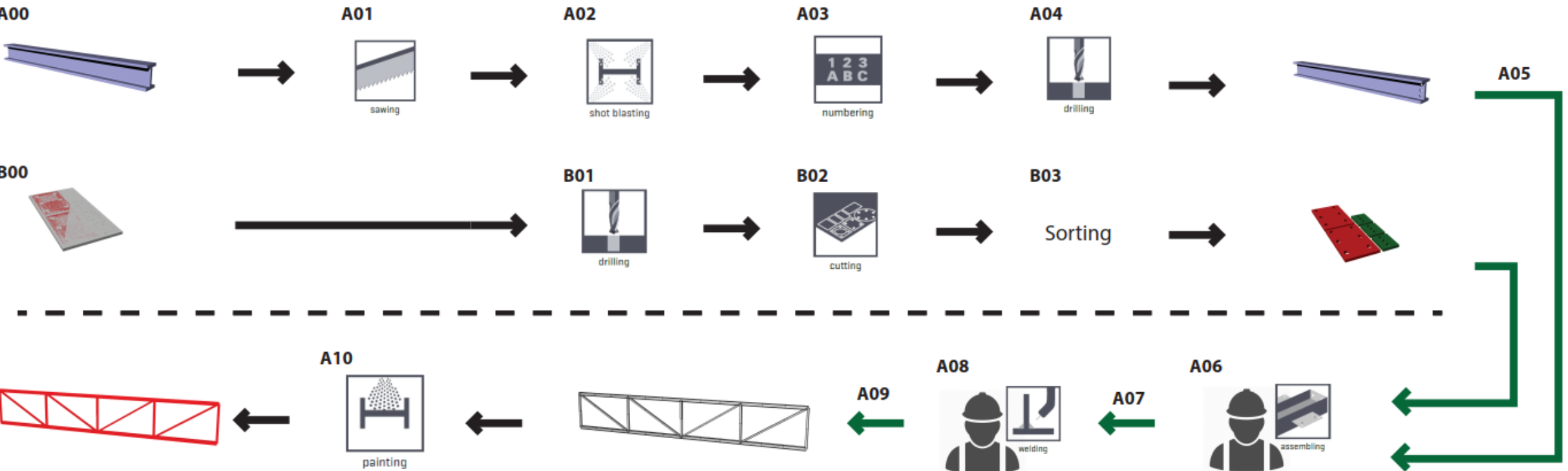
Production costs: 100 %  
Weight: 3424 kg,- (S355)  
Welding Volume: 764 cm<sup>3</sup>, -  
Sawing Cuts: 53 pcs.  
Double Miter Connections: 16 pcs  
Surface Area: 108 m<sup>2</sup>



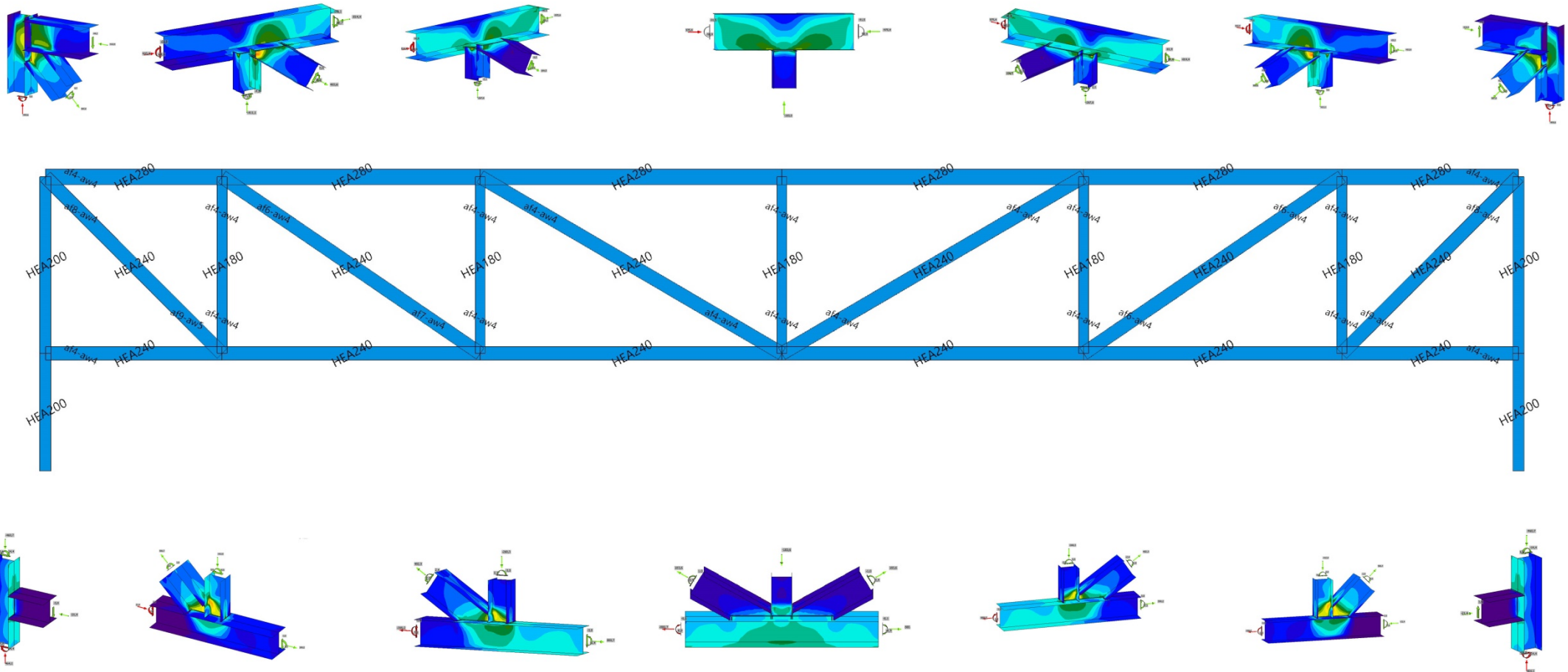
# Las optimalisatie



# Kostenmodel



# Geoptimaliseerde vakwerken



# Toepassing



# 1. Instellen parameters

<b>Number</b>	<b>Variable</b>	<b>Unit</b>
1	Height Structure	m
2	Length	m
3	Minimal weld size	mm
4	Height Truss	mm
5	Segments	pcs
6	Truss-typology	Truss-type
7	Material	Steel-grade
8	Cross-section Chords and Columns	Cross-section Family
9	Cross-section Diagonals and Posts	Cross-section Family
10	Buckling length chords	m
11	Eccentricity Topchord	mm
12	Eccentricity Bottomchord	mm

## 2. Berekenen alle varianten

- Size optimization
- Full strength welds
- 10 sec / variant



Typology

☒ Pratt

☐ Warren

Steelgrade

☒ S235

☐ S275

☐ S355

Posts and Diagonals

☒ HEA

☐ HEB

☐ HEM

☐ RHSC

☐ SHSC

Segments

3 16

out:#DoubleMiterCuts

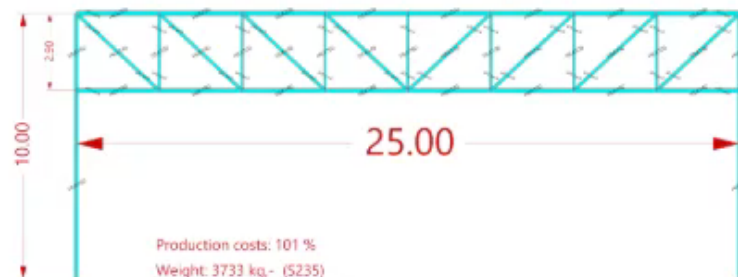
0 40

AngleMin

0.00 67.38

Truss-height [mm]

1000 3000



Production costs: 101 %  
 Weight: 3733 kg,- (S235)  
 Welding Volume: 633 cm3,-  
 Sawing Cuts: 53 pcs.  
 Double Miter Connections: 16 pcs  
 Painting Area: 114 m2

Weight [kg]

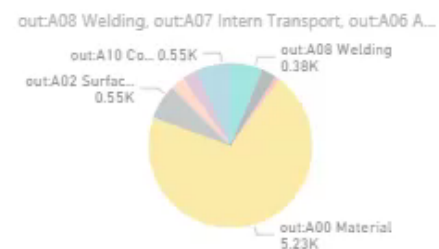
1,080.43

8,747.55

Production cost in p...

37.59

288.39



Truss-height [mm]

out:BucklingLength

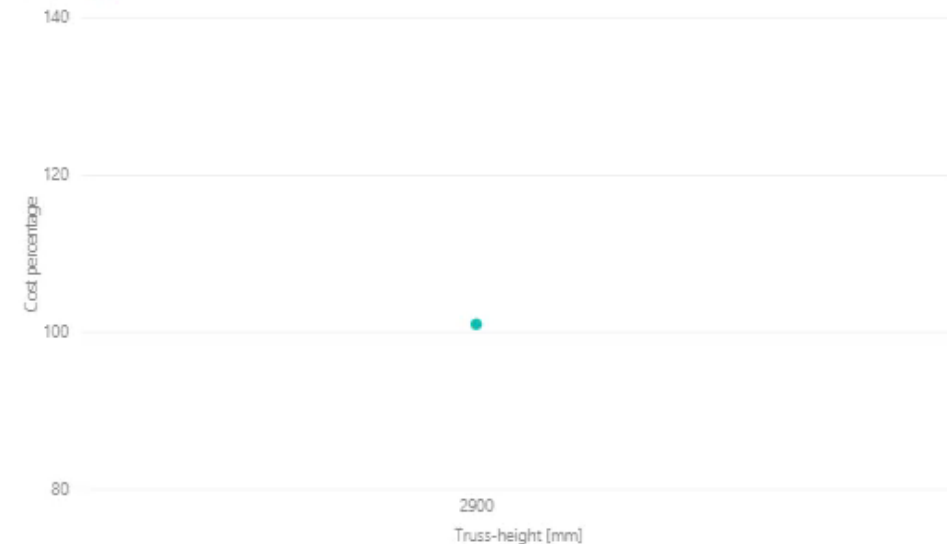
6.25

Segments

Truss-height [mm]	4	6	8	10	12	14	16
3000	97.21	92.59	89.55	86.68	83.98	81.44	79.07
2900	97.04	92.18	89.04	86.14	83.41	80.85	78.57
2800	96.86	91.87	88.69	85.78	83.04	80.47	78.18
2700	96.69	91.56	88.34	85.42	82.67	80.09	77.79
2600	96.51	91.35	88.10	85.17	82.41	79.82	77.51
2500	96.34	91.16	87.88	84.94	82.17	79.57	77.26
2400	96.16	90.97	87.66	84.71	81.93	79.33	77.01
2300	95.99	90.78	87.45	84.49	81.70	79.10	76.78
2200	95.81	90.59	87.24	84.27	81.47	78.86	76.54
2100	95.64	90.41	87.04	84.06	81.25	78.64	76.32
2000	95.46	90.22	86.83	83.84	81.03	78.42	76.10
1900	95.29	90.03	86.62	83.63	80.81	78.20	75.89
1800	95.11	89.84	86.41	83.42	80.60	77.99	75.68
1700	94.94	89.65	86.20	83.21	80.38	77.77	75.47
1600	94.76	89.46	85.99	83.00	80.17	77.56	75.26
1500	94.59	89.27	85.78	82.79	79.95	77.35	75.05
1400	94.41	89.08	85.57	82.58	79.74	77.14	74.84
1300	94.24	88.89	85.36	82.37	79.53	76.93	74.63
1200	94.06	88.70	85.15	82.16	79.32	76.72	74.42
1100	93.89	88.51	84.94	81.95	79.11	76.51	74.21
1000	93.71	88.32	84.73	81.74	78.90	76.30	74.01

Cost percentage over truss-height

Segments 8



HEA200

First out:CSS\_Topchord

HEA180

First out:CSS\_Bottomchord

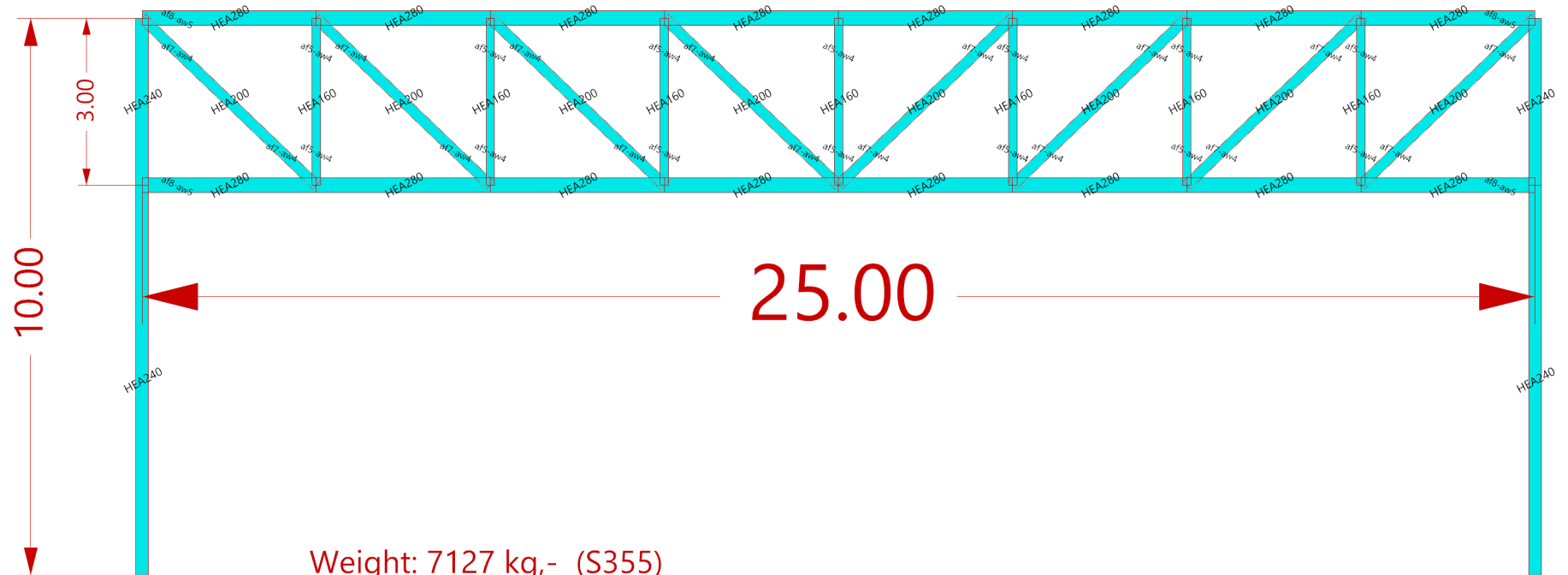
HEA100

First out:CSS\_Post

HEA140

First out:CSS\_Diagonal

### 3. Kies variant



Weight: 7127 kg,- (S355)

Welding Volume: 1626 cm<sup>3</sup>,-

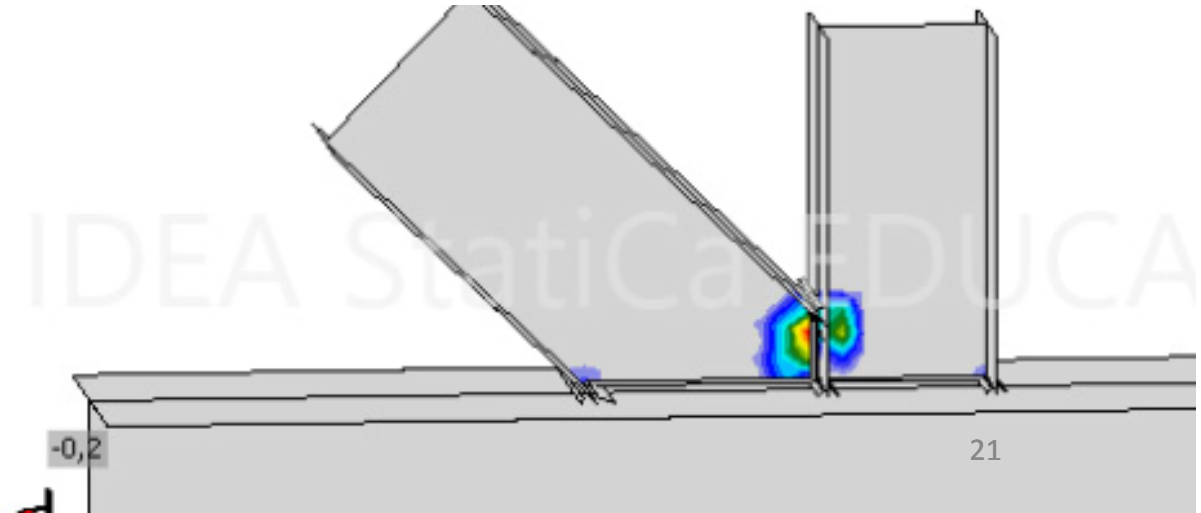
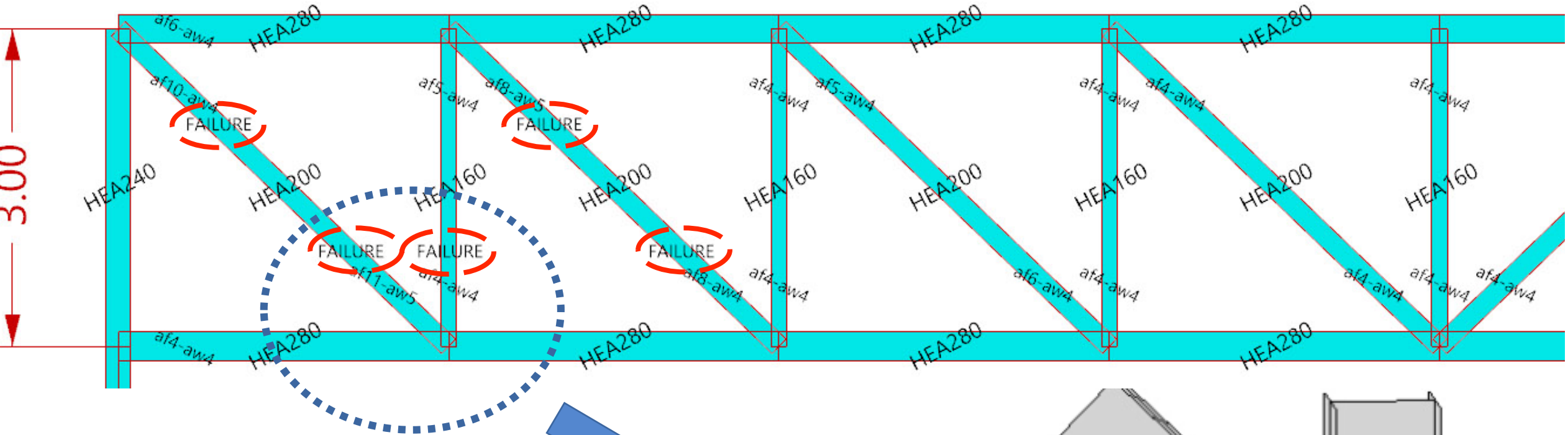
Sawing Cuts: 53 pcs.

Double Miter Connections: 16 pcs

Surface Area: 170 m<sup>2</sup>



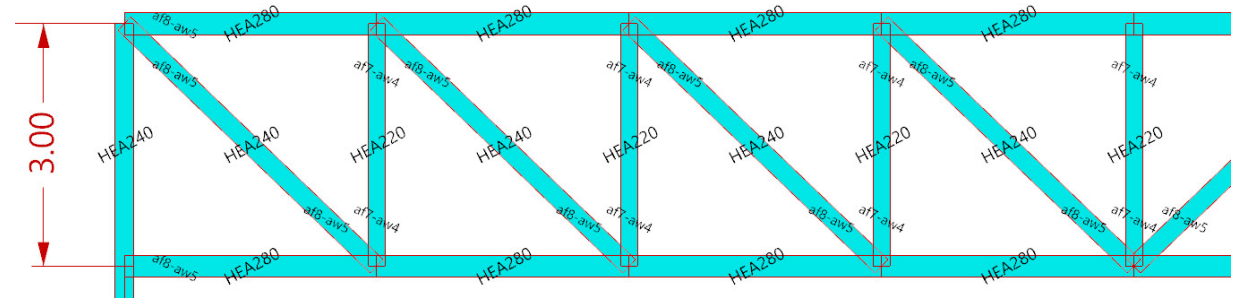
# 4. Detailberekening



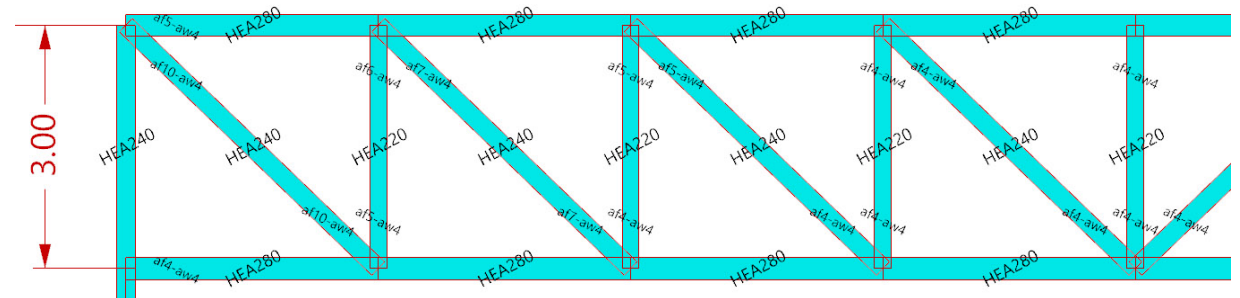
# Detailberekening

$$a = t * \sqrt{\frac{\beta^2 \gamma_{M2}^2 f_y^2 (2 (\cos(\omega))^2 + 1)}{f_u^2}}$$

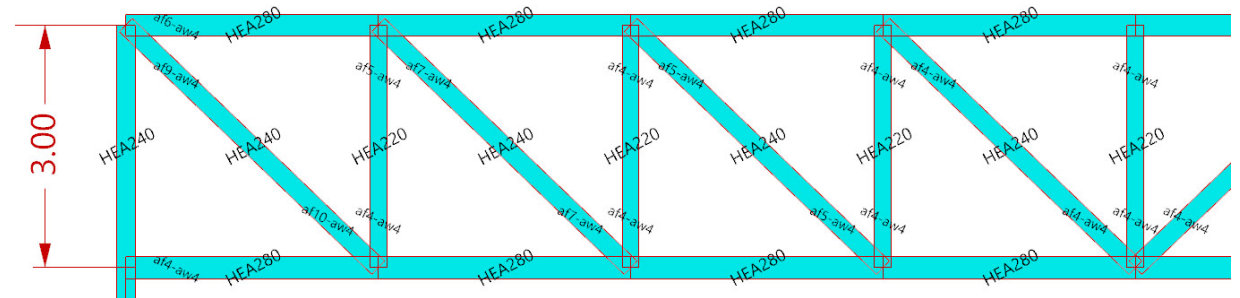
Full-strength



IDEA:  
Scharnierend



IDEA:  
Momenvast

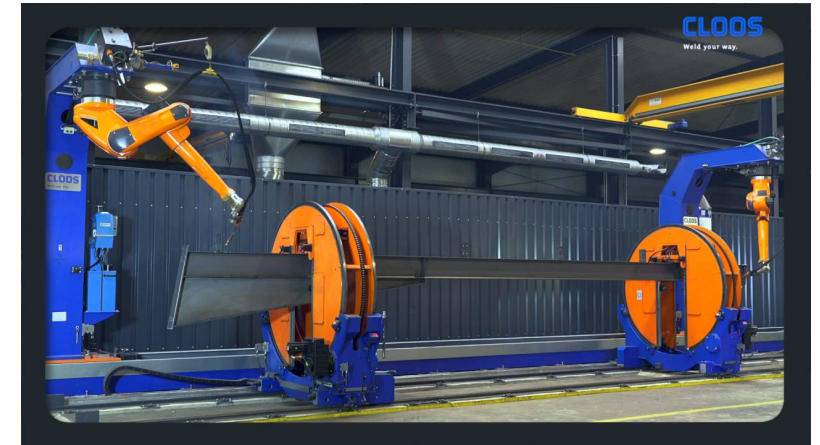
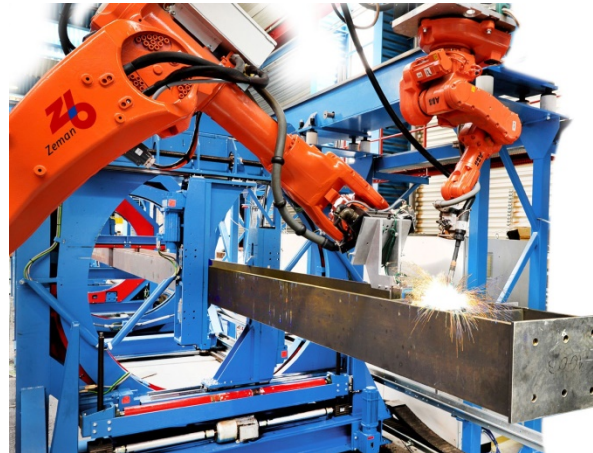
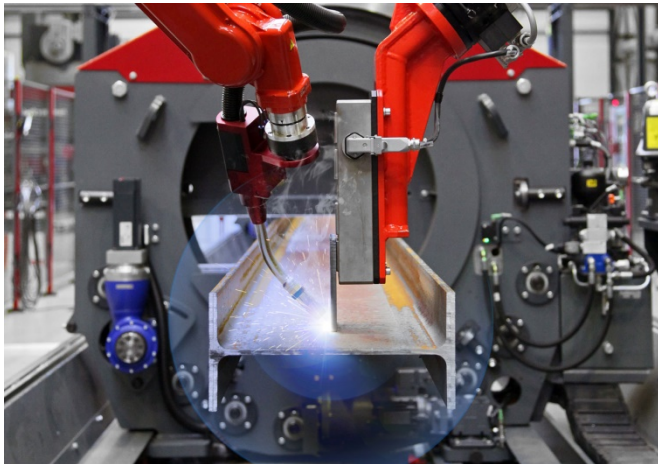
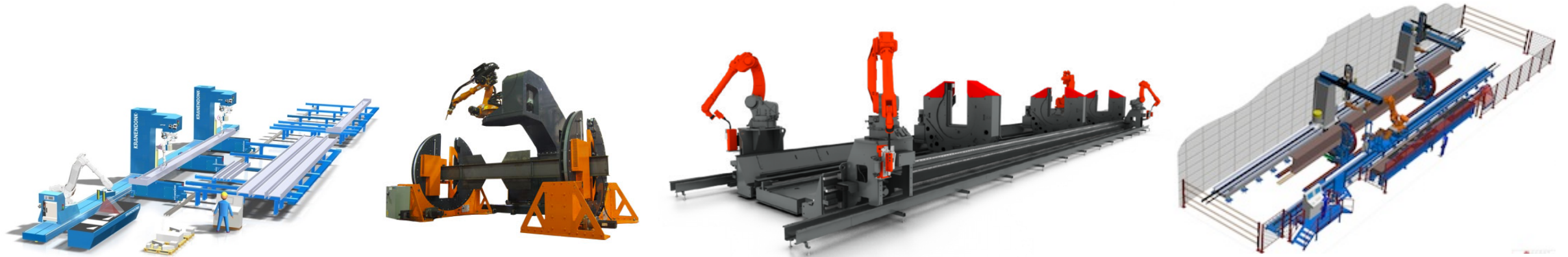


# 5. Vergelijk

	Aanname	Gewicht	Lasberekening	Las volume	Kosten
Size optimization		7127 kg	Directional	1467 cm3	
Detail berekening		8175 kg	Full strength	2640 cm3	100 %
Detail berekening	Scharnier	8175 kg	Directional	1592 cm3	97 %
Detail berekening	Momentvast	8175 kg	Directional	1541 cm3	96.5 %

# Industry 4.0

Geautomatiseerd assembleren en lassen





# Constructeur en Staalbouwer

**Constructeur**



**Staalbouwer**



# Nieuwe methodiek

Engineering

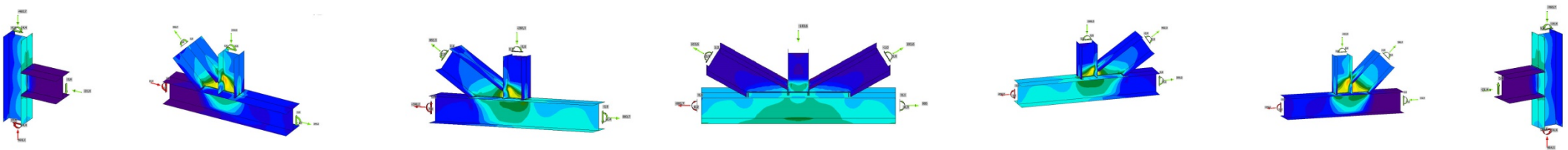
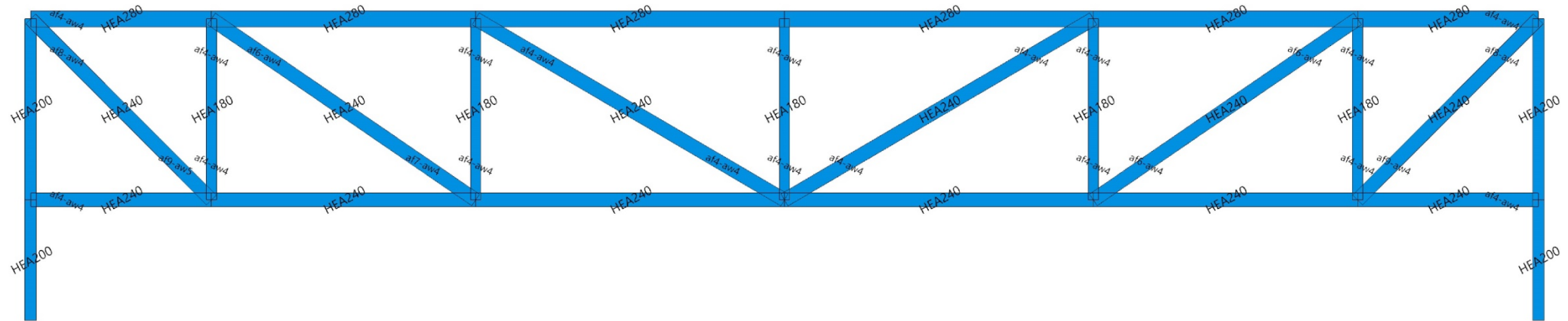
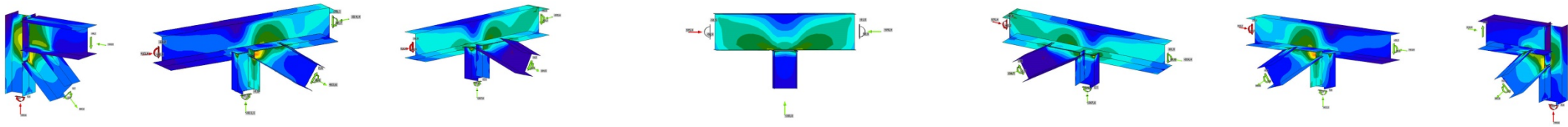


Productie



Inspectie





## Aknowledgements

TU Delft

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IDEA Statica UK,

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