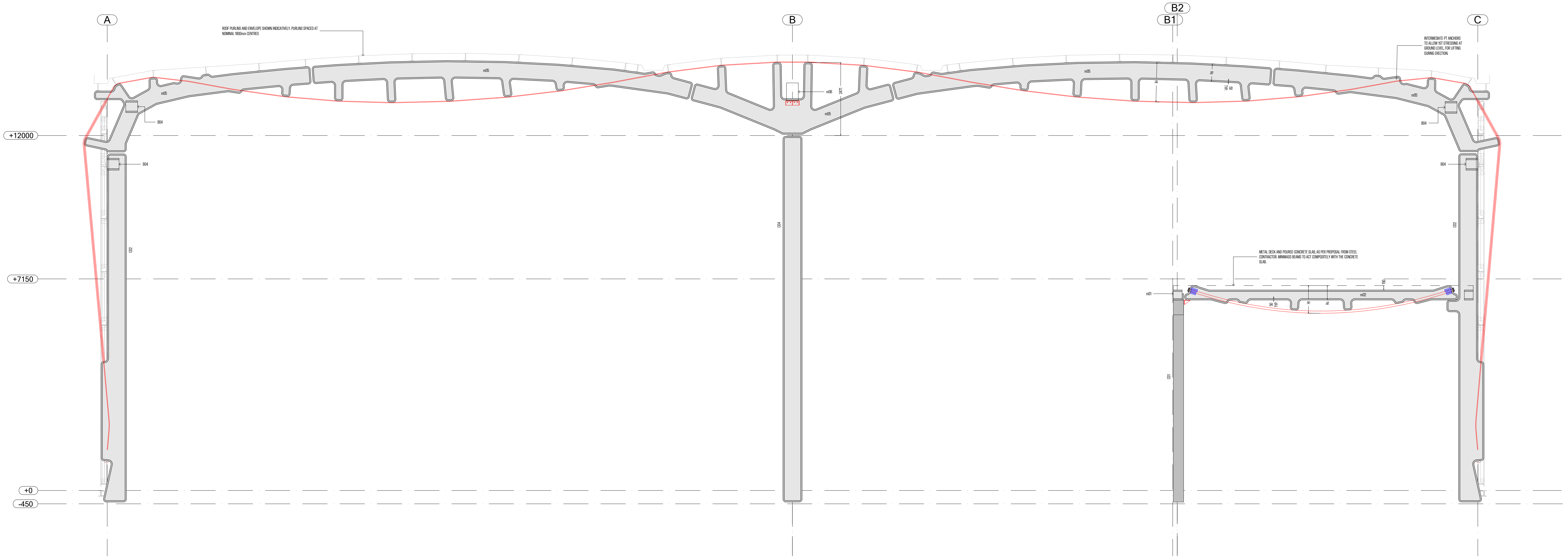

minimass portal frame warehouse

Case Study, June 2025

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Contents

status: for information
date: 30/06/2025
by: ARC
rev: 00

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1.0 Summary

A detailed comparison study has been carried out for the design of a 48,000 sqft (4,445 sqm), two bay portal frame warehouse unit. The client has shared the steel contractor's drawings, with sizes and design loading and the minimass team has replicated the design of the same building, using the minimass system as the primary structural frame, instead of structural steel. Design information and assumptions are provided in the following pages of this report, as well as a selection of plan, elevation and section drawings.

For this project, the minimass solution can achieve a 38% reduction in embodied carbon for effectively the same price. As well as a very significant carbon saving, the minimass approach can achieve a predicted reduction in the overall timeline of 3 weeks.

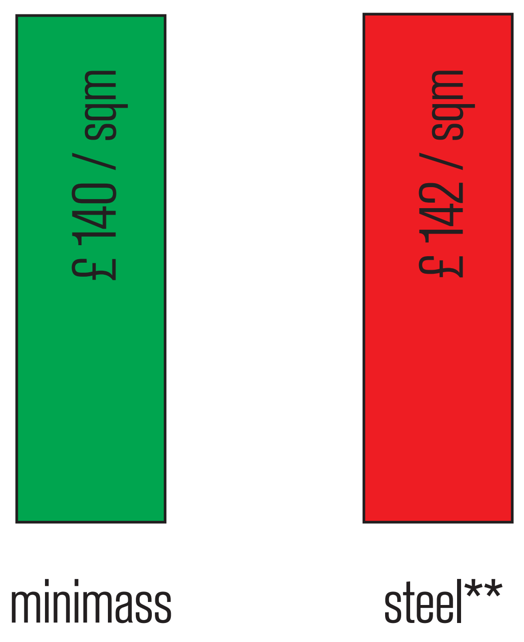
These are major reductions that show the value of the minimass approach.

For more information about minimass, please refer to our website, www.minimass.net

2.0 Cost, time & carbon comparison

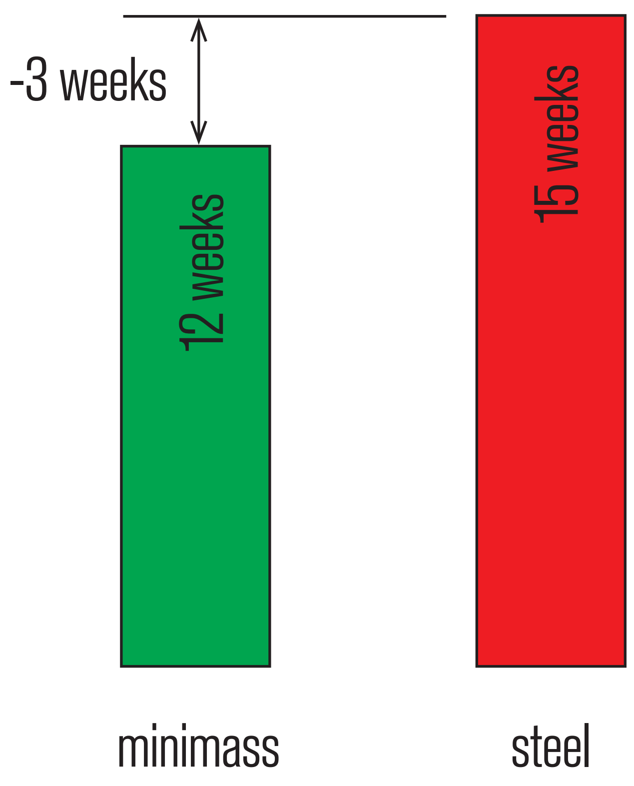
Cost*

price parity



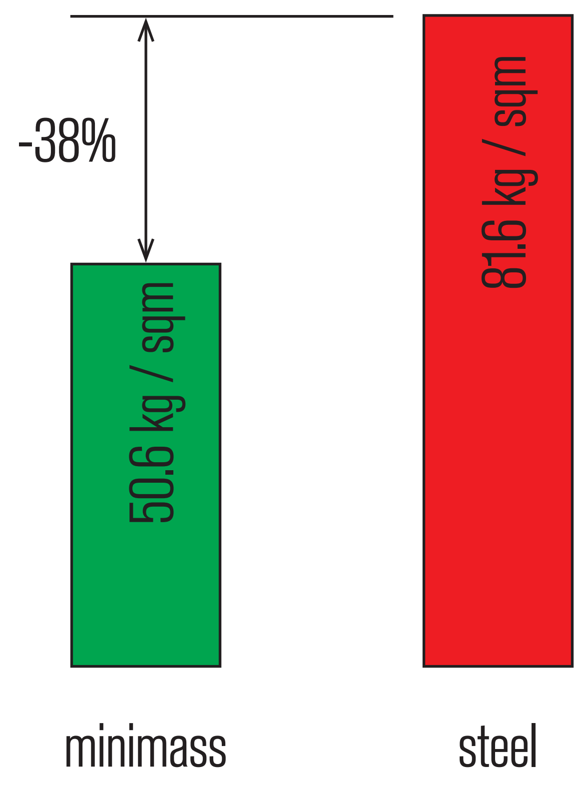
Time

3 weeks faster



Carbon

38% saving



* includes prelims, design, supply of elements, connections and installation

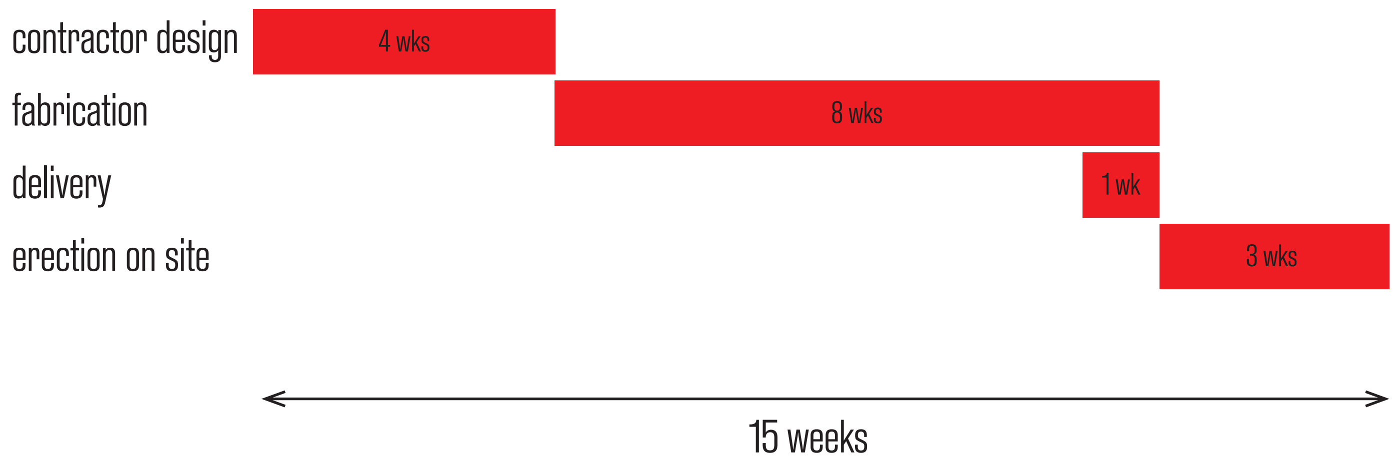
** based on recent tender pricing for open and closed sections.

3.0 Procurement and construction

The procurement and construction comparison here is for the primary structural frame only, on the basis that the other parts of the building will be the same for a minimass frame or a steel frame. Steel and minimass are directly comparable in this sector.

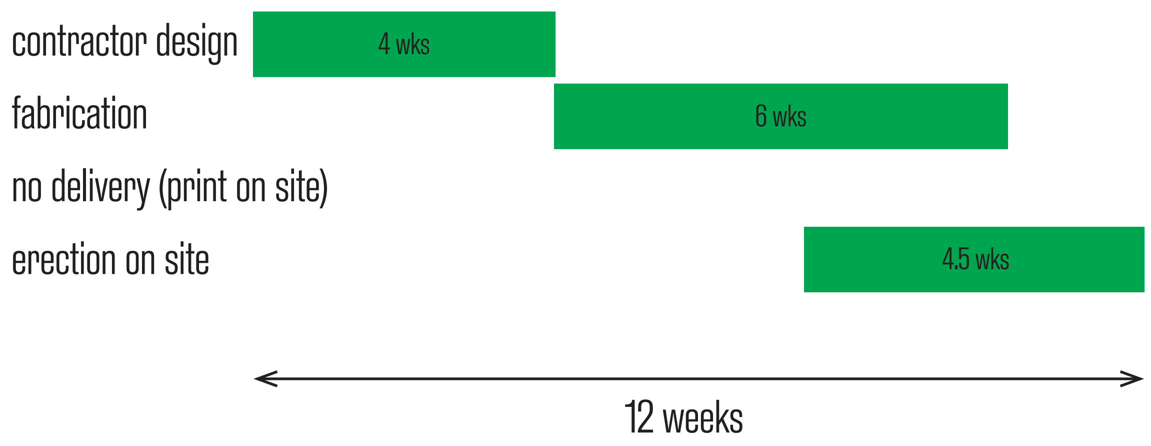
3.1 Steel construction programme

For a typical steel industrial building the lead-in time (time from order to arrival of elements on site) is expected to be approximately 12 weeks. This would break down into a period for contractor design / detailing followed by fabrication and delivery. For erection, a typical gang of 4 people, with a crane and MEWPs would erect 1,500 sqm of steelwork per week. For the schedule below, we have assumed 1 gang on site, requiring a total of 3 weeks for erection of the full 4,445 sqm.

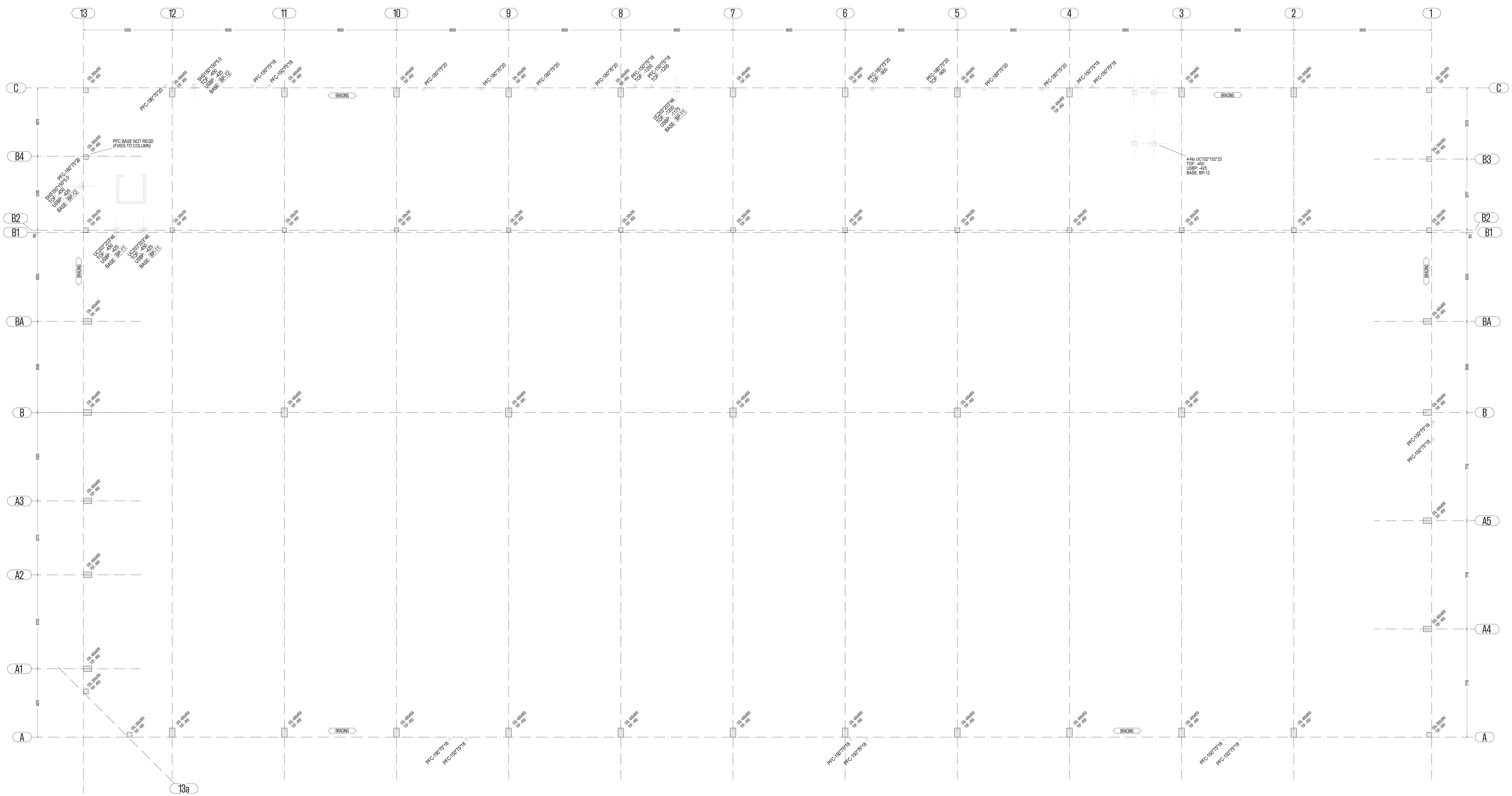


3.2 minimass construction programme

The printer is able to print at a speed of 250mm/s, which translates to 3100m of printer layer per working day (allowing for breaks, downtime, set up, wash out etc). We estimate that this project will therefore require 21 full days of printing spread out over 5 weeks. Each piece requires 7 days from the start of printing to being ready to transport and erect. Ideally, the printer would be set up for manufacture on site (adjacent to the construction area). That would allow all transport to be avoided. However, if there is not enough space on site, then the pieces can be manufactured off-site and delivered, with the site of manufacture being as close to the construction site as possible. At 1,000 sqm installed per week per gang (compared to 1,500 sqm for steel), this project would require 4.5 weeks assembly on site.



4.0 Drawings



COLUMN SETTING OUT PLAN - UNIT 1

NOTES:
- Work to figured dimensions only.
- All dimensions given in mm unless noted otherwise.
- 3D printed concrete to to be fck = 40MPa.
- infill concrete to be RC 40/50.
- PT tendon to be grade Y1860S.
- Corrosion strategy:
  - 3D printed concrete: provide sufficient cover to the embedded reinforcement.
  - PT cables: adequate corrosion protection for PT strands within the building envelope is provided by the greased and sheathed HDPE covering to each individual strand. PT strands outside the building envelope shall have an additional outer duct which is to be filled with grout / grease / wax.
- PT stressing sequence:
  - 1st (factory) stressing: varies depending on element, refer to sections and details.
  - 2nd (site) stressing: varies depending on element, refer to sections and details.
- Fire protection strategy:
  - provide adequate concrete cover to achieve 60 mins fire protection on the concrete.
  - no fire protection measures are required for the external PT tendons unless noted otherwise.

Dark grey fill indicates 3D printed concrete.

Grey fill indicates infill concrete.

minimass BEAM TABLE:

REF.	B	Hc	Ht	nPT	precamber
m01	300	490	900	7	0
m02	300	490	900	5	+25
m03	300	390	700	5	+25
m04	300	390	700	5	+25
m05	400	550	varies	3	N/A
m06	400	550	varies	8	N/A

RC BEAM TABLE:

REF.	B	H	notes
B01	300	300	trimming beam
B02	400	600	L1 edge beam
B03	300	300	roof bracing
B04	400	400	roof edge beam
B05	300	400	roof trimming beam
B06	350	500	roof beam

COLUMN TABLE:

REF.	B	H	notes
C01	350	350	
C02	400	600	
C03	400	650	
C04	450	650	
C05	310	310	

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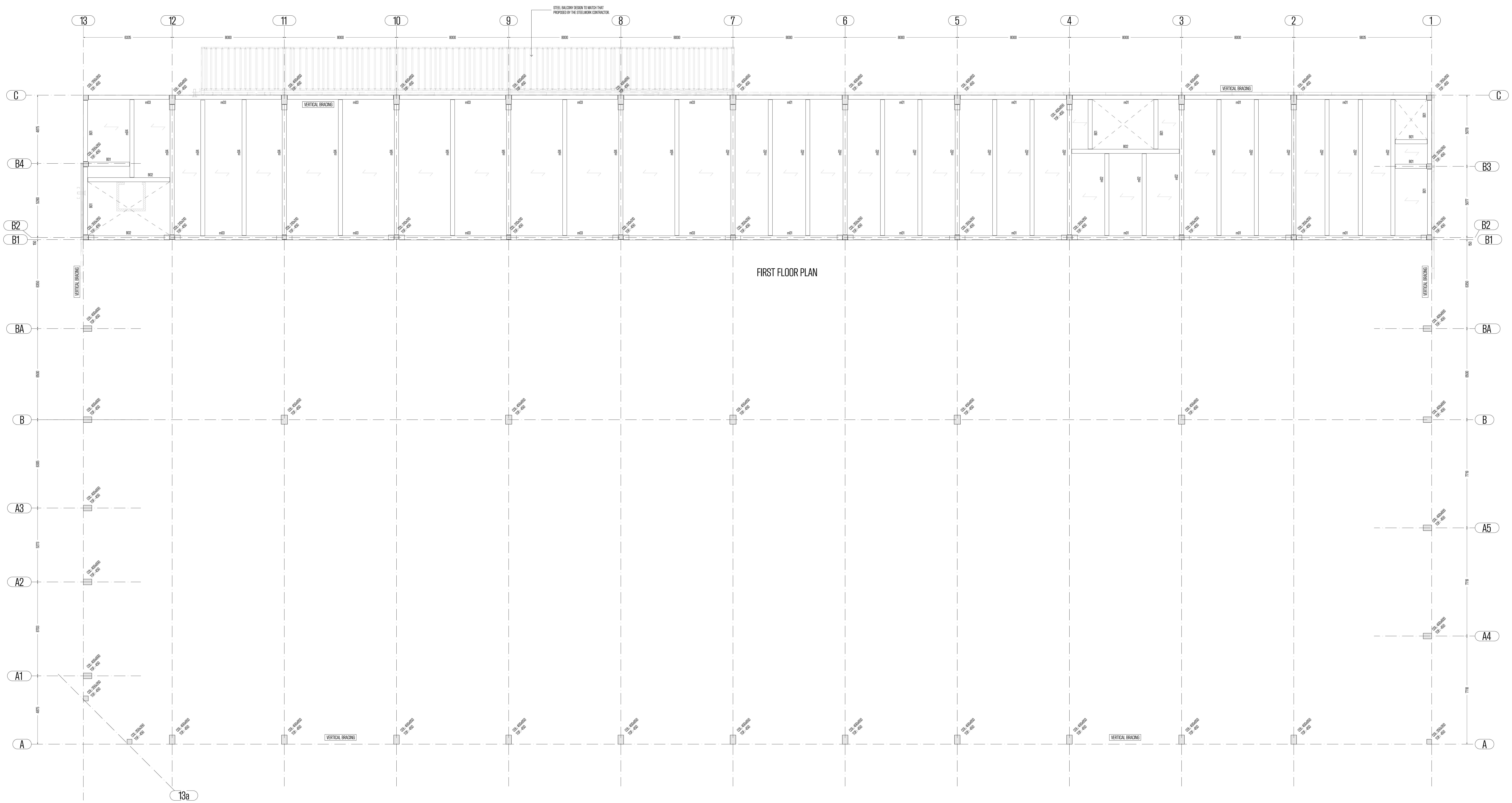
COLUMN GA

DATE:	23/06/2025
BY:	ARC
SCALE:	1:100 @ A0
DRAWING:	S001
REVISION:	00



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B03	300	300	roof bracing
B04	400	400	roof edge beam
B05	300	400	roof trimming beam
B06	350	500	roof beam

COLUMN TABLE:

REF.	B	H	notes
C01	350	350	
C02	400	600	
C03	400	650	
C04	450	650	
C05	310	310	

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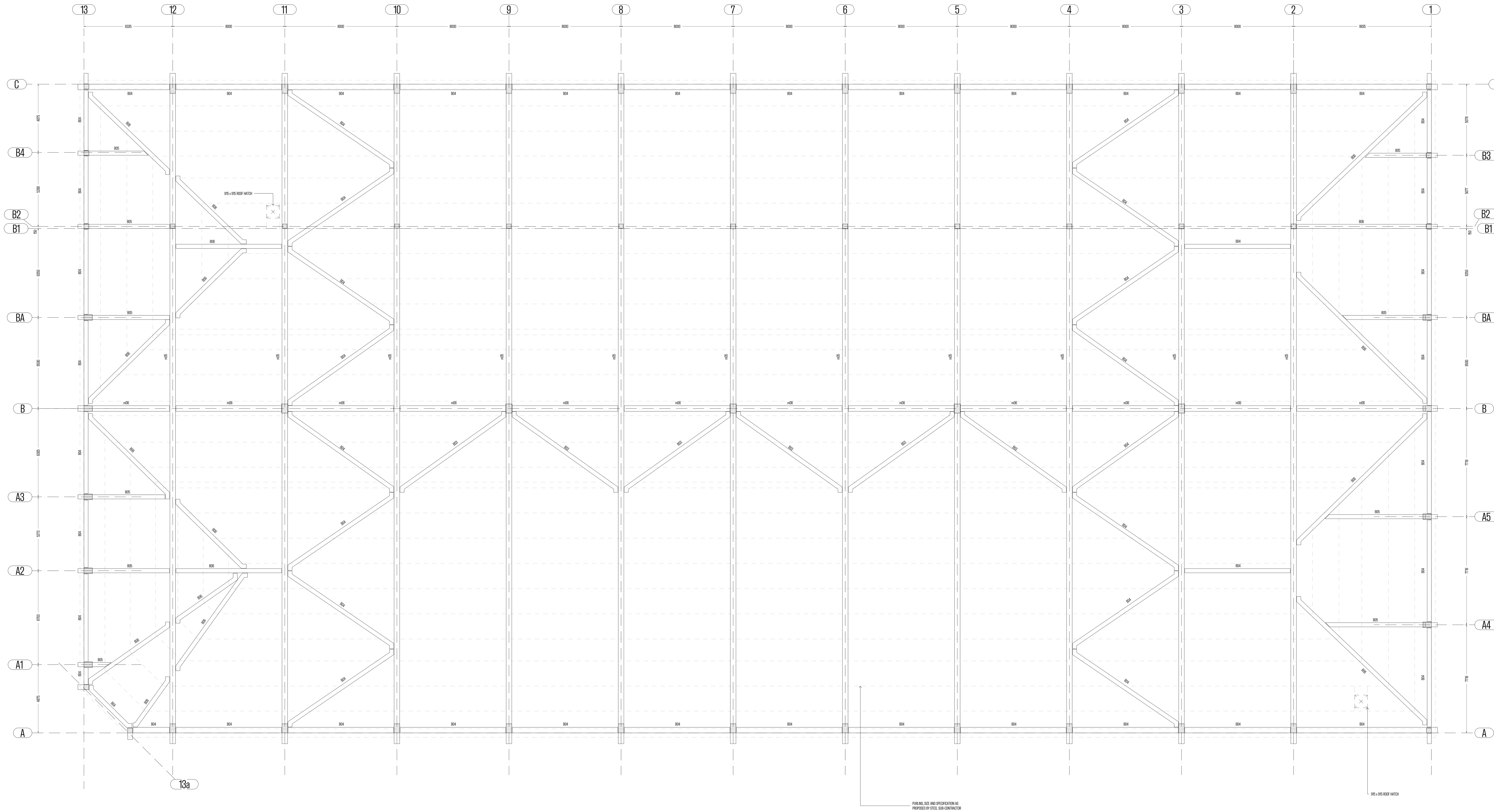
WAREHOUSE CASE STUDY

LEVEL 01 GA

DATE: 23/06/2025
BY: ARC
SCALE: 1:100 @ A0
DRAWING: S002
REVISION: 00



ROOF PLAN

NOTES:

- Work to figured dimensions only.
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minimass BEAM TABLE:

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m02	300	490	900	5	+25
m03	300	390	700	5	+25
m04	300	390	700	5	+25
m05	400	550	varies	3	N/A
m06	400	550	varies	8	N/A

RC BEAM TABLE:

REF.	B	H	notes
B01	300	300	trimming beam
B02	400	600	L1 edge beam
B03	300	300	roof bracing
B04	400	400	roof edge beam
B05	300	400	roof trimming beam
B06	350	500	roof beam

COLUMN TABLE:

REF.	B	H	notes
C01	350	350	
C02	400	600	
C03	400	650	
C04	450	650	
C05	310	310	

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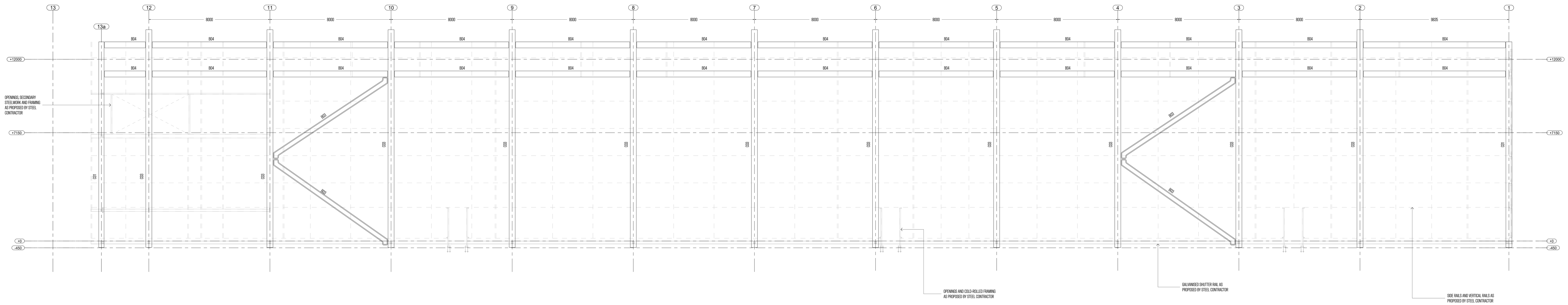
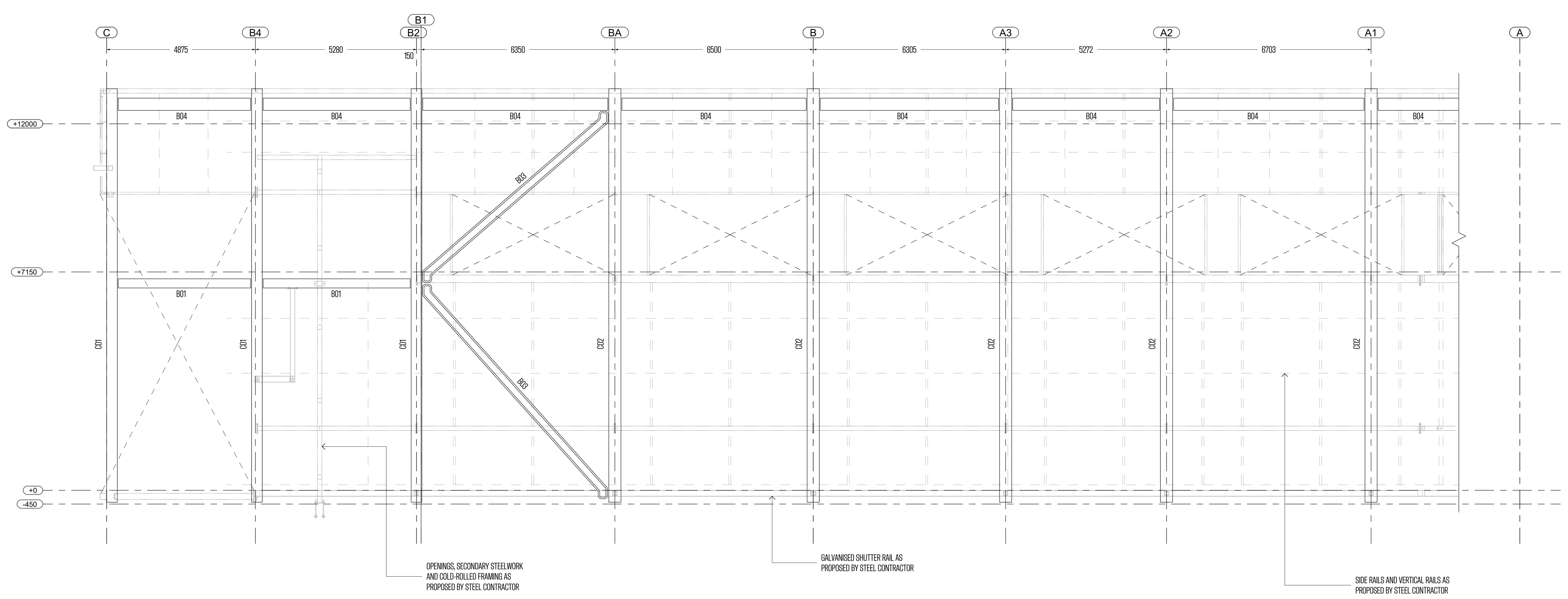
WAREHOUSE CASE STUDY

ROOF GA

DATE:	23/06/2025
BY:	ARC
SCALE:	1:100 @ A0
DRAWING:	S003
REVISION:	00



ELEVATION ON GRIDLINE A



ELEVATION ON GRIDLINE 13

NOTES:
- Work to figured dimensions only.
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B03	300	300	roof bracing
B04	400	400	roof edge beam
B05	300	400	roof trimming beam
B06	350	500	roof beam

COLUMN TABLE:

REF.	B	H	notes
C01	350	350	
C02	400	600	
C03	400	650	
C04	450	650	
C05	310	310	

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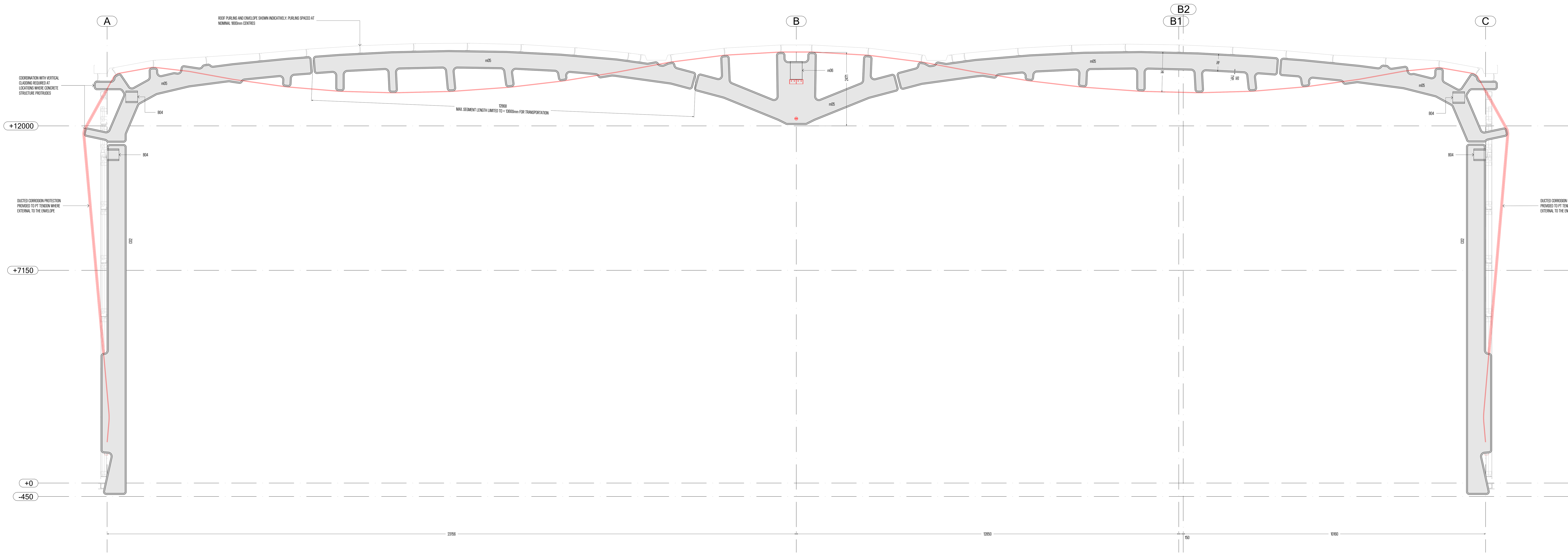
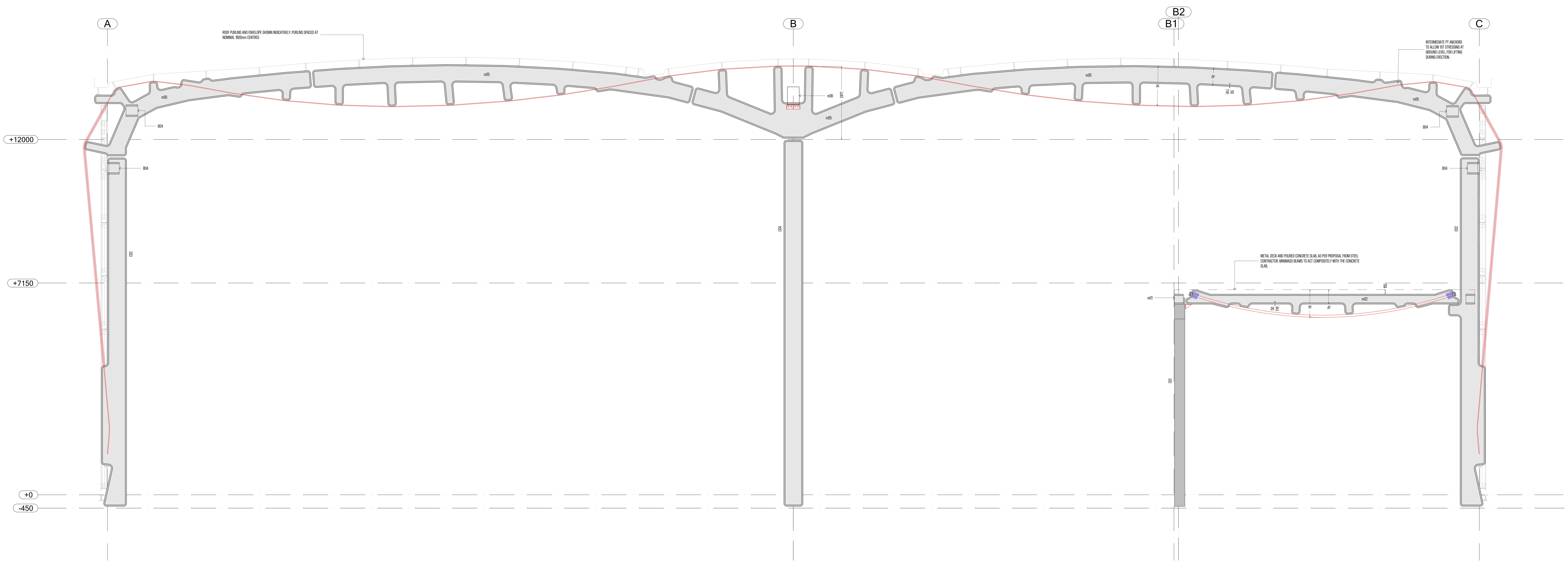
ELEVATION GRIDLINES A & 13

DATE: 23/06/2025
BY: ARC
SCALE: 1:100 @ A0
DRAWING: S010
REVISION: 00





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C01	350	350	
C02	400	600	
C03	400	650	
C04	450	650	
C05	310	310	

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WAREHOUSE CASE STUDY

SECTION GRIDLINES 2 & 3

DATE:	23/06/2025
BY:	ARC
SCALE:	1:50 @ A0
DRAWING:	S020
REVISION:	00

5.0 Technical design

The following list of assumptions and performance specifications lays out the basis of design for the minimass structure. Loads and minimum requirements have been provided by the client.

5.1 Size and shape

B	=	16 m	primary grid width
B_{sec}	=	8 m	secondary beam spacing (roof purlin span)
L	=	23.1 m	primary grid length
H	=	12 m	eaves height of the building (underside of the structure at the roof / column interface)
n_L	=	2	no. of bays in the span direction
n_B	=	12	no. of bays in the width direction (this can be increased or reduced to suit)
$\sum L$	=	46.3 m	total building width
$\sum B$	=	96.2 m	total building length

5.2 Lateral stability

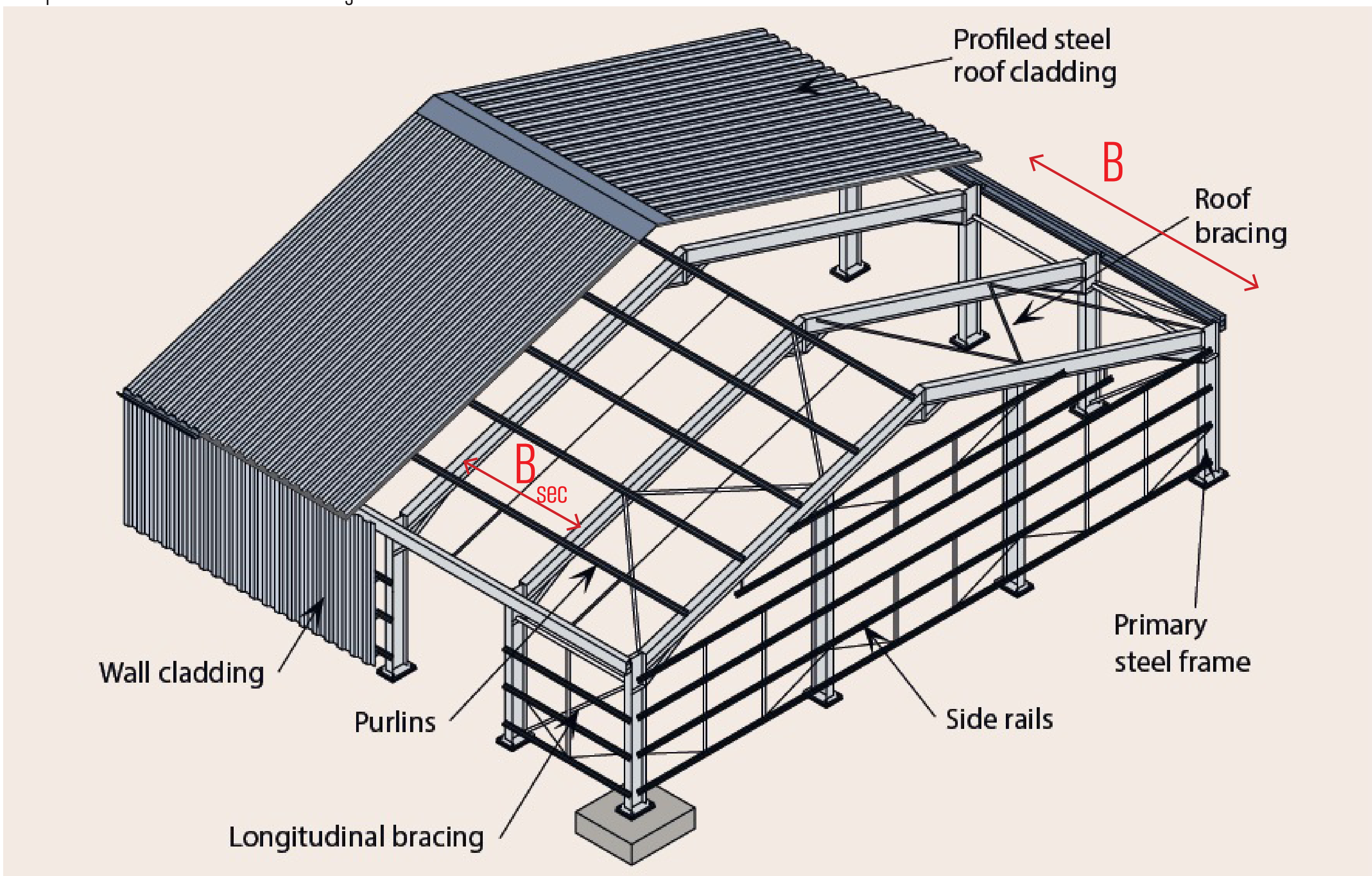
In the span direction, the portal frame structure will provide the lateral stability. In the orthogonal direction to the portal frames, vertical cross bracing will be provided in the perimeter walls.

5.3 Roof build up

The roof surface is a structural metal deck that spans between cold-rolled purlins. The purlins span between the rafter beams, with a length of 8 m and a spacing of 1.8m (typ). This solution has been developed following the proposal to use Kingspan products as indicated in the steel contractor's drawings. Thermal insulation, roof skylights and hung services are all assumed to be incorporated in this design.

Rainwater drainage is provided by gravity fed gutters positioned at the perimeter and along two lines at the central area.

Example steel frame for an industrial building.



Schematic showing typical elements of an industrial building.

5.4 Materials

3D printed concrete	=	f_{ck} = 40 MPa (8mm aggregate)
infill concrete	=	RC40/50 (10mm aggregate)
mild steel reinforcement	=	B500B, f_y = 500 MPa, nominal cover = 30mm (min)
PT cables	=	Y1860S, f_y = 1860 MPa, 15.7mm diameter

5.5 Permanent loads

(kN/m²)	mezzanine (office)	mezzanine (store)	roof
Metfloor 60, 150 slab	2.73	2.73	-
decking + mesh	0.4	0.4	0.18
services + ceilings	0.5	0.5	0.25
raised access floor	0.25	0.0	0.0
PV	0.0	0.0	0.15
beam self-weight	as calculated	as calculated	as calculated
total	3.88 + s/w	3.63 + s/w	0.58 + s/w

5.6 Variable loads

(kN/m²)	mezzanine (office)	mezzanine (store)	roof
imposed load	4.0	12.5	0.6
partitions	1.0	0.0	0.0
total	5.0	12.5	0.6

5.7 Wind loads

$q_p(z)_x$	=	0.617 kPa	peak velocity pressure, X-dir (portal frame)
F_{wx}	=	596 kN	wind force acting in X-dir (portal frame)
$q_p(z)_y$	=	0.837 kPa	peak velocity pressure, Y-dir (along)
F_{wy}	=	572 kN	wind force acting in Y-dir (along)

Vertical wind loads (uplift and pressure) to be included in zones according to BS EN 1991-1-4.

5.8 Wall cladding

The external walls to the building will use the same system and design as proposed by the steel contractor i.e. cold-rolled side rails and metal cladding.

5.9 Fire protection

If this is required by the project, the external PT tendons would be wrapped in fire protective material, to achieve the relevant fire protection classification. The concrete elements have inherent fire resistant characteristics on the basis of adequate cover to the reinforcement.

5.10 Concrete connections

Refer to section 6.0 for further details.

5.11 Construction sequence

A detailed construction sequence has not been prepared for this specific case study, however, installation options can be described on reqeust.

6.0 Concrete connections

Traditional concrete structures - even when using precast elements - will usually rely on "cast-in" or grouted dowel connections between pieces. The speed of these connection types is the primary drawback for concrete element construction compared to structural steel construction - which has very fast and well understood connections.

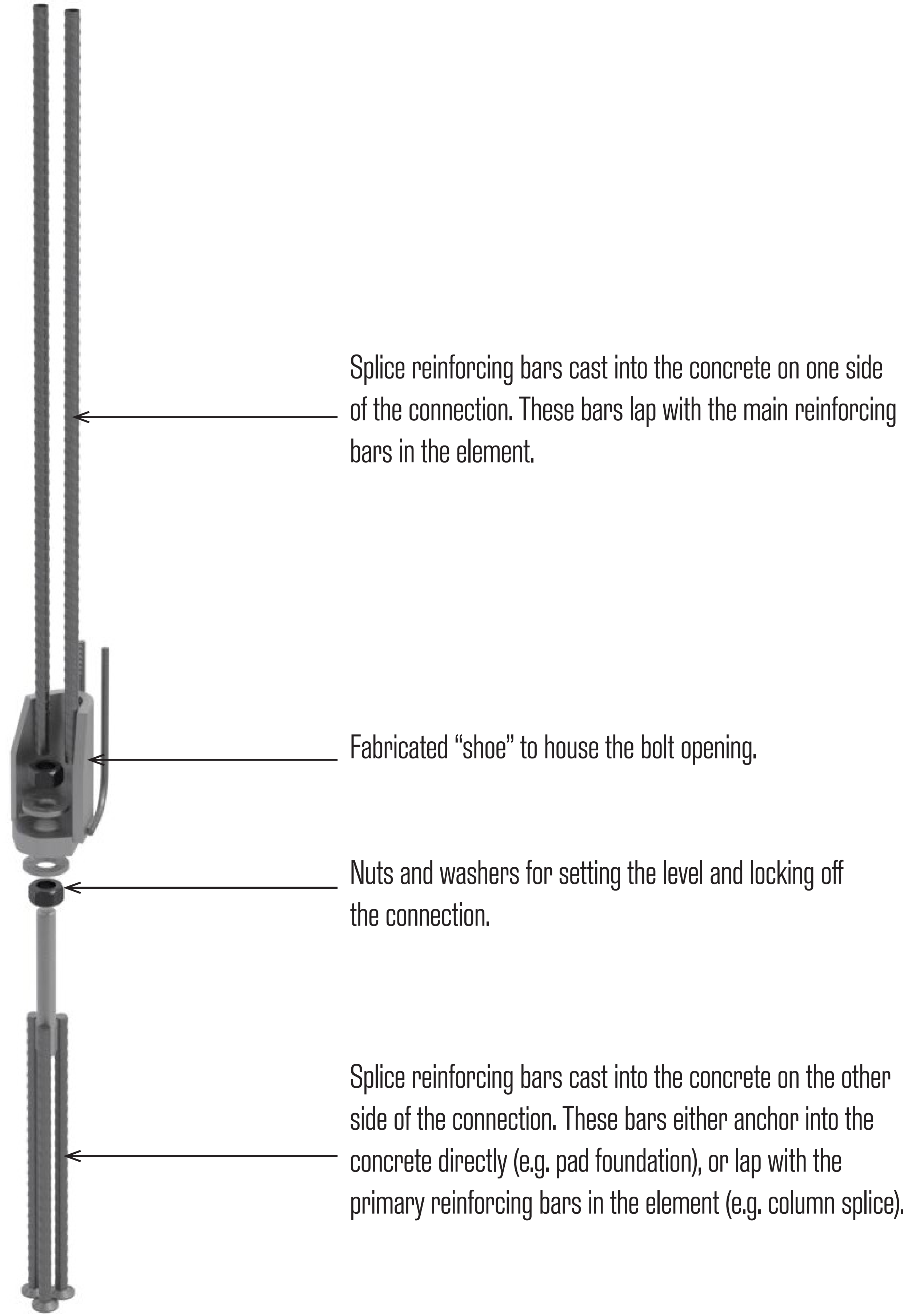
However, the minimass approach is to use bolted connections - for immediate connection strength and stiffness - but applied to concrete structures. This has become possible in recent times with the innovation in precast concrete connection technology, driven by suppliers such as Peikko. This method allows the transfer of tension, compression and shear directly across a joint using bolts which lap with reinforcement embedded on either side. Typically a gap is included between the two elements, to allow for positional tolerance, which is then grouted after the bolts are tightened. Whilst grout is still used in this case, the temporary (construction stage) loading is accommodated within the capacity of the bolts themselves, therefore the connection is strong enough immediately for erection to continue without waiting.

Bolted concrete connections are typically used in conditions where two parallel surfaces must be joined, e.g. for a column connecting to the top of a pad foundation, or for a beam connecting to the side of a column. For situations where other orientations are required, e.g. the connection of a diagonal brace member, this system does not work, without some sort of design intervention. However, this is precisely what minimass has achieved - where the steel industry has the ability to fabricate any connection geometry, minimass has the ability to design and manufacture any concrete connection geometry.

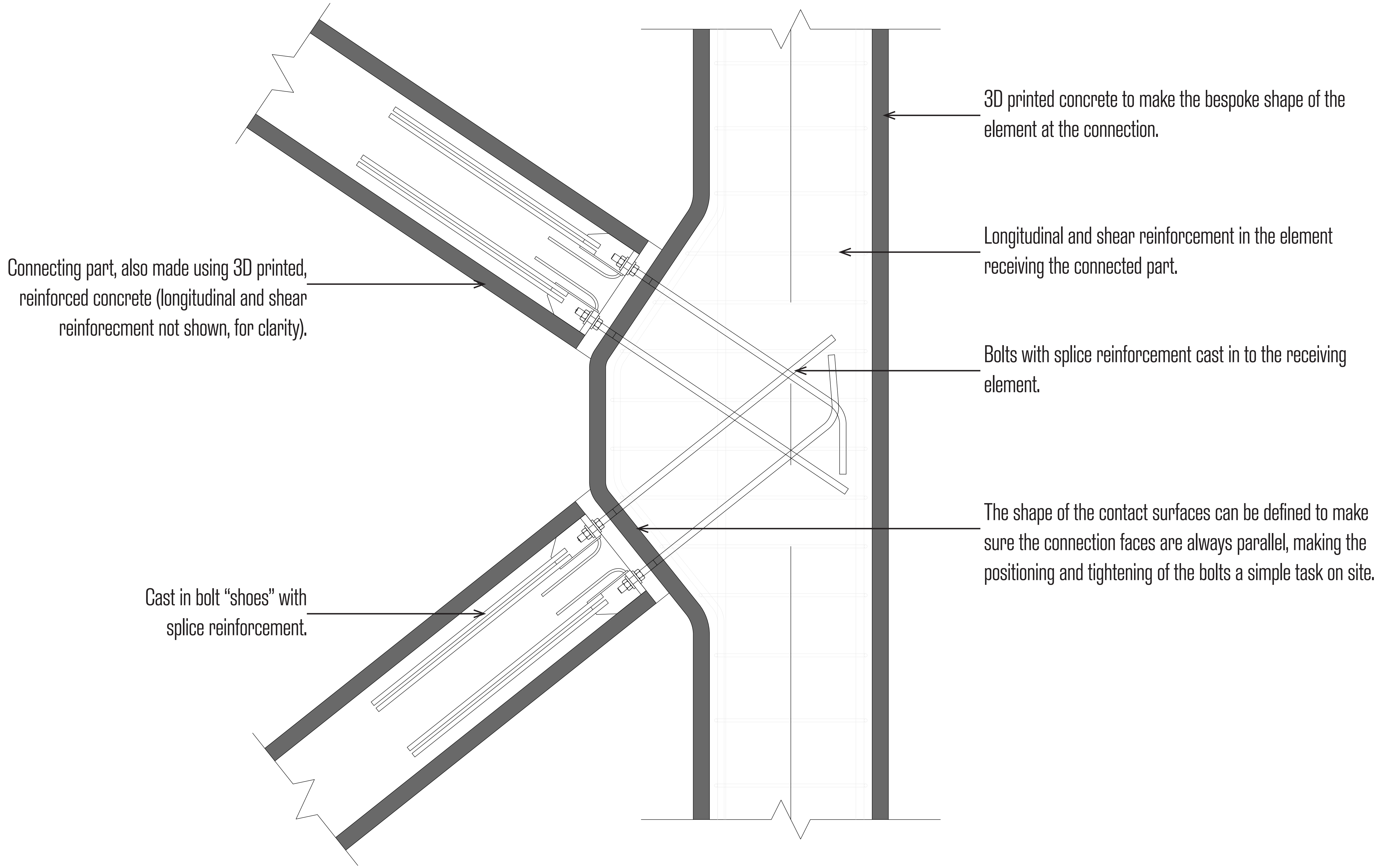
The use of these components generates a big increase in the speed of installation of concrete structures, bringing the erection time of a bolted concrete structure down to the same level as that of a traditional steel frame.

Peikko website image: concrete bolted connection during erection.

Peikko website image: concrete elements prefabricated with bolt locations.



Peikko website image: components of a bolted connection.



minimass bolted cross bracing connection, schematic design

APPENDIX

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A1: Detailed mass and carbon calculations

								per Functional element						steel design				total building mass — minimass						original	total building CO2e — minimass		original	
Element	Ref.	Functional element count	Total length m	Functional unit length	width m	height m	print path length m	3DCP kg	infill concrete kg	longitudinal rebar mass kg	shear rebar mass kg	no. PT strands	PT mass kg	steel design cross-section	length m	no.	mass kg	3DCP kg	concrete kg	rebar kg	PT kg	no. connections nr	total printed path length m	steel kg	CO2e kg	CO2e/m2 kg/m2	CO2e kg	CO2e/m2 kg/m2
Beams																												
mezz_store_primary beams	m01	11	91,67	8,33	0,3	0,49	191	620	1676	94,54	32	7	74,9	UB 686x254x152	9,35	2	1634	6820	18436	1389	824	11	1592	3269	6261	1,4	17563	3,9
														UB 533x210x82	8	8	754							6035				
														UB 457x152x60	8	1	552							552				
mezz_store_secondary beams	m02	19	176,4	9,28	0,3	0,49	224	729	1846	134,94	35	5	61,5	UB 457x191x74	10	4	851	13851	35074	3236	1168	38	2080	3404	11755	2,6	30617	6,9
														UB 533x210x82	10	11	943							10373				
														UB 686x254x125	10	2	1438							2875				
														UB 406x140x39	5,9	2	265							529				
mezz_office_primary beams	m03	11	86,33	7,85	0,3	0,39	177	605	1754	89,03	25	5	54,6	UB 356x127x33	6,335	1	240	6655	19294	1256	601	22	1389	240	5794	1,3	9576	2,2
														UB 533x210x82	8	1	754							754				
														UB 457x152x52	8	8	478							3827				
														UB 457x152x60	8	1	552							552				
mezz_office_secondary beams	m04	12	112,15	9,35	0,3	0,39	219	582	1686	135,84	30	5	68,3	UB 356x127x33	5,56	1	211	6984	20232	1990	820	24	2047	211	7033	1,6	13655	3,1
														UB 533x210x82	10	2	943							1886				
														UB 457x152x52	10	7	598							4186				
														UB 457x152x60	10	2	690							1380				
beam_main portal frame	m05	22	532,51	24,205	0,39	0,55	935	3020	13325	366,83	76	3	145,0	UB 457x152x52	22,37	12	1338	66431	293157	9746	3191	66	22632	16053	63227	14,2	58679	13,2
														UB 457x191x74	22,37	4	1904							7615				
														UB 457x152x60	22,37	6	1544							9261				
beam_ internal transfer	m06	12	89,76	7,48	0,4	0,55	209	764	3585	132,59	18	8	84,5	UB610x305x149	8,46	4	1450	9168	43020	1591	1014	24	1563	5798	10418	2,3	23977	5,4
														UB 610x229x101	8	4	929							3717				
														UB 610x229x113	7,58	4	985							3940				
mezz_trimming beam	B01	9	32,89	3,65	0,3	0,3	79	263	526	26,53	10	0	0	UB 305x102x28	4,045	3	130	2367	4734	326	0	18	289	391	1249	0,3	2421	0,5
														UB 406x178x60	5,28	1	364							364				
														UB 203x133x25	2,8	3	81							242				
														UB 254x146x31	5,0775	2	181							362				
mezz_trimming beam	B02	4	28,67	7,1675	0,4	0,6	202	688	3440	89,54	22	0	0	UB 610x229x101	8	1	929	2752	13760	446	0	8	1448	929	2608	0,6	4104	0,9
														UB 533x210x82	8	1	754							754				
														UB 356x171x45	6,335	1	328							328				
														UB 305x165x40	6,335	1	291							291				
beam_ edge_ along bays	B04	15	86,45	5,76	0,4	0,4	160	553	1659	65,38	17	0	0,0	CHS 139.4x4.0	6,10	15	94	8295	24885	1232	0	30	922	1410	5558	1,2	10353	2,3
														SHS 150x150x5	6,10	15	156							2347				
beam_ edge_ across bays	B04	26	193,48	7,44	0,4	0,4	204	715	2143	84,42	22	0	0	CHS 139.4x4.0	8,41	9	130	18590	55718	2757	0	52	1518	1166	12445	2,8	13982	3,1
														SHS 150x150x5	7,91	14	203							2839				
														CHS 114.3x3.0	7,55	15	71							1068				
beam_edge_mid_elevation	B04	16	128,34	8,02	0,4	0,4	219	713	2140	91,00	23	0	0	SHS 150x150x5	8,02	16	206	11408	34240	1829	0	32	1757	3291	7762	1,7	9071	2,0
beam_roof_trimming	B05	10	60,57	6,06	0,3	0,4	129	436	1309	68,71	15	0	0	UB 356x171x45	6,84	4	354	4360	13090	836	0	20	781	1415	3085	0,7	4633	1,0
														UB 254x146x31	5,54	6	197							1184				
beam_roof_eaves	B06	17	147,46	8,67	0,35	0,5	220	728	2913	153,75	18	0	0	UB 254x146x31	9,71	9	346	12376	49521	2922	0	34	1908	3116	10874	2,4	12778	2,9
														UB 203x133x25	3,24	6	93							559				
														UB 356x171x45	9,86	4	510							2040				
														UB 305x165x40	8,00	2	368							736				
														UB 254x146x37	8,46	2	360							720				
Columns																												
col_corner_edge	C01	9	112,50	12,50	0,35	0,35	308	1050	2625	141,80	35	0	0	UC 254x254x73	13,539	3	1137	9450	23625	1591	0	18	3850	3410	5865	1,3	14788	3,3
														UB 406x178x54	13,539	2	841							1682				
														UB 406x140x39	13,539	3	607							1822				
														UC 254x254x89	13,539	1	1386							1386				
col_mezz_store	C01	6	43,02	7,17	0,35	0,35	180	602	1505	81,34	20	0	0	UC 254x254x107	7,225	3	889	3612	9030	609	0	6	1291	2667	2242	0,5	8706	2,0
														UC 254x254x89	7,225	3	739							2218				
col_edge_braced	C02	9	112,50	12,50	0,4	0,6	341	1200	6000	443,14	32	0	0	UB 406x140x39	13,539	6	607	10800	54000	4274	0	18	4263	3643	12411	2,8	10765	2,4
														UB 406x178x54	13,539	2	841							1682				
														UB 406x140x46	13,539	1	716							716				
col_edge_portal frame	C03	22	259,01	11,77	0,4	0,65	323	1183	6680	342,24	32	0	0	UB 610x229x125	13,539	5	1946	26026	146960	8227	0	22	3803	9731	30359	6,8	67227	15,1
														UB 610x229x140	13,539	4	2180							8719				
														UB 610x229x113	13,539	2	1759							3519				
														UB 533x210x92	13,539	11	1432							15757				
col_ internal	C04	5	61,85	12,37	0,5	0,585	391	1484	7199	548,16	35	0	0	UB 610x305x179	13,539	5	2787	7422	35997	2914	0	10	4837	13935	8361	1,9	24832	5,6
col_mezz_office	C05	5	35,85	7,17	0,31	0,31	165	533	1120	81,34	17	0	0	UC 254x254x73	7,225	5	607	2665	5600	492	0	5	1183	3033	1550	0,3	5404	1,2
Bracing																												
brace_roof_hor_diagonals	B03	6	56,31	9,39	0,3	0,3	194	676	1352	68,14	25	0	0	CHS 114.3x3.0	8,43	9	80	4056	8112	559	0	12	1821	718	2141	0,5	1979	0,4
brace_verticals	B03	12	108,68	9,06	0,3	0,3	187	652	1305	65,75	24	0	0	SHS 120x120x4.0	8,475	4	138	7824	15660	1078	0	24	1694	554	4131	0,9	7921	1,8
														SHS 180x180x5.0	9,85125	4	306							1224				
														SHS 160x160x5.0	10,02	4	274							1097				
brace_roof_hor_diagonals	B04	16	150,00	9,38	0,4	0,4	254	900	2701	159,53	27	0	0	CHS 168.3x4.0	9,32727	11	174	14400	43216	2988	0	32	2381	1911	10383	2,3	10279	2,3
														CHS 114.3x3.0	8,195	20	78							1551				
														CHS 139.7x4	8,665	2	134							267				
Totals		274	2706															256312	967361	52286	7617	526	65046	193252	225509	50,6	363312	81,6

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A2: Cost plan and comparison

These are feasibility level estimates and do not constitute a formal quote for the work.

25/06/2025

SUMMARY

DESCRIPTION		MINIMASS OPTION VALUE	STRUCTURAL STEEL OPTION VALUE
PRECON, PRELIMINARIES		£ 64.629,76	£ 41.879,68
DESIGN		£ 28.795,66	£ 48.110,84
CONCRETE MEASURED WORKS		£ 423.449,68	£ 5.612,32
STEELWORK MEASURED WORKS		£ 107.874,11	£ 539.205,81
TOTAL		**£ 624.749,21**	**£ 634.808,65**
	/sqm	140,55	142,81

PRECON, PRELIMINARIES

Item	Bill description	Unit	MINIMASS Bill quantity	MINIMASS Rate	MINIMASS Amount	STEEL Bill quantity	STEEL Rate	STEEL Amount
A	**CONSTRUCTION DESIGN , PRECON AND PRELIMINARIES**							
P4	**Pre Construction / Design Management**							
P5	Project Manager	wks	4,00	3.165,28	12.661,12	4,00	3.165,28	12.661,12
P5	**Construction Phase Management**							
P6	Project Manager	wks	5,00	3.165,28	15.826,40	3,00	3.165,28	9.495,84
P8	Site Engineer	wks	5,00	2.527,20	12.636,00	3,00	2.527,20	7.581,60
P9	Safety Supervisor	wks	5,00	517,95	2.589,75	3,00	517,95	1.553,85
P11	Storeman/Traffic Marshall	wks	5,00	1.381,21	6.906,05	3,00	1.381,21	4.143,63
P7	Site Welfare, Office, compound, security , water, power, hoarding	wk	-		BY OTHERS	-		BY OTHERS
P9	Local on site stores	wks	5,00	24	120,00	3,00	24	72,00
P10	Transport/on/off	nr	2,00	210	420,00	2,00	210	420,00
P11	Erect/Dismantle	nr	2,00	342,72	685,44	2,00	342,72	685,44
	Communications							
P12	Internet Connection	sum	1,00	1.200,00	1.200,00	1,00	1.200,00	1.200,00
P13	Rental	Qtr	3,00	96	288,00	3,00	96	288,00
P14	Calls	wks	5,00	42	210,00	3,00	42	126,00
P15	Copier	wks	5,00	30	150,00	3,00	30	90,00
P16	Stationary	wks	5,00	18	90,00	3,00	18	54,00
P12	Site two way radios	wks	5,00	14,4	72,00	3,00	14,4	43,20
	Printer on site							
	set up / take down and protect	PROV SUM	1,00	-	5.000,00			EXCLUDED
	Miscellaneous Plant Not in Rates							
P15	Setting out instruments	wks	5,00	234	1.170,00	3,00	234	702,00
P16	Cube Tank	wks	5,00	54	270,00	3,00	54	162,00
	Temporary electrics							
P17	Task lighting (tripods)	week	5,00	120	600,00	3,00	120	360,00
P18	Leads	week	5,00	60	300,00	3,00	60	180,00
P19	Transformers	week	5,00	81	405,00	3,00	81	243,00
P11	**Skips**							
P12	Concrete Washout	wks	5,00	336	1.680,00	3,00	336	1.008,00
P12	Rubbish skips 8yrd/8t	wks	5,00	270	1.350,00	3,00	270	810,00
					64.629,76			**41.879,68**

STRUCTURE DESIGN

Item	Bill description	Unit	MINIMASS Bill quantity	MINIMASS Rate	MINIMASS Amount	STEEL Bill quantity	STEEL Rate	STEEL Amount
	STRUCTURE DESIGN							
T	Design Manager	wks	3	3.160,16	9.480,48	6	3.160,16	18.960,96
U	Detailing	wks	5	1.966,94	9.834,70	10	1.966,94	19.669,40
V	Design Engineer	wks	3	3.160,16	9.480,48	3	3.160,16	9.480,48
					28.795,66			**48.110,84**

CONCRETE MEASURED WORKS

Item	Bill description	Unit	MINIMASS Bill quantity	MINIMASS Rate	MINIMASS Amount	STEEL Bill quantity	STEEL Rate	STEEL Amount
	CONCRETE MEASURED WORKS							
[003]	**GROUNDWORKS**							
B3	**Installation of new warehouse structure - base slab / foundations**							
B33	Cast in concrete; base plate and bolts for connection ground slab with steel columns UB45- BASED ON FREE ISSUED	nr	-	100,22	0,00	56,00	100,22	5.612,32
	minimass holding down bolts included in connections elsewhere							
	sub total				**0,00**			**5.612,32**
B4	**WAREHOUSE STRUCTURE**							
1	Beams	m	1.767,00	149,11	263.475,26			EXCLUDED
2	Columns	m	625,00	137,12	85.697,88			EXCLUDED
3	Bracing	m	315,00	102,21	32.196,54			
1	Allowance connections	PROV SUM	526,00	80	42.080,00			EXCLUDED
					423.449,68			**5.612,32**

STEELWORK MEASURED WORKS

Item	Bill description	Unit	MINIMASS Bill quantity	MINIMASS Rate	MINIMASS Amount	STEEL Bill quantity	STEEL Rate	STEEL Amount
	STEELWORK AND CLADDING MEASURED WORKS							
	Materials							
A	Beams	t	-	-	N/A	111,04	1.990,39	221.012,59
B	Columns	t	-	-	N/A	73,92	1.736,48	128.360,80
C	Bracing	t	-	-	N/A	7,32	2.780,53	20.353,51
I	Holding down bolts	nr	-	-	N/A	224	5,4	1.209,60
J	Fittings	t	-	-	N/A	9,61	3.036,00	29.188,10
J	Transport	nr	-	-	N/A	20	1.320,00	26.400,00
	assumes the minimass pinter is set up on site, avoiding the need for transport cost							
K	Finishing, estimate e.g. fire protection	m2	4400	7,5	33.000,00	4400	15	66.000,00
	sub total				**33.000,00**			**492.524,60**
	Install frame							
N	Install Frame	t	2.707,00	26,18	70.874,11	201,89	231,22	46.681,21
	Post-tensioning labour	days	10,00	400,00	4.000,00	0,00	0,00	0,00
	sub total				**74.874,11**			**46.681,21**
					107.874,11			**539.205,81**

A3: Carbon assumptions

Embodied carbon calculations are based on the methodology outlined in the document, “How to calculate embodied carbon”, 2nd edition, published by the Institution of Structural Engineers. Unlike the calculations for complete structures or buildings, the comparison here is well defined and simple to assess. For each beam type, the mass of concrete, reinforcement, steel and timber has been estimated, then multiplied by the appropriate weighting factor.

The weighting factors that have been used are as follows, with all units given as kg CO2e / kg of material:

stage	A1 - A3	A1 - A5	A - C	D	sequestration	notes
poured concrete	0.130	0.133	0.143	-0.007	0	IStructE Carbon tool v3, UK C40/50 (25% GGBS)
printed concrete	0.129	0.143	0.161	0	0	Constructionarium bridge project mix design, with embodied carbon estimated based on constituent materials, with data from ICE database v3.0. C30/37, 360 kg/m^3 CEM II/A-L, 130 kg/m^3 limestone fines, admixtures.
reinforcement	0.720	0.862	0.872	0.438	0	IStructE carbon tool v3, UK 97% recycled EAF production
PT strand	1.724	1.986	1.996	-0.850	0	IStructE carbon tool v3, Europe average
mild steel (open)	1.740	1.782	1.792	-0.910	0	IStructE carbon tool v3, UK open rolled steel sections
mild steel (closed)	2.590	2.756	2.766	-1.610	0	IStructE carbon tool v3, UK open rolled steel sections

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