



The Leadenhall Building

Reflections on a megaframe

Damian Eley

Arup

CTBUH 12 June 2013

Engineering systems

The challenge of the megaframe

Efficiency and buildability

Managing movements

Lessons learned

The Leadenhall Building

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Engineering systems

The challenge of the megaframe

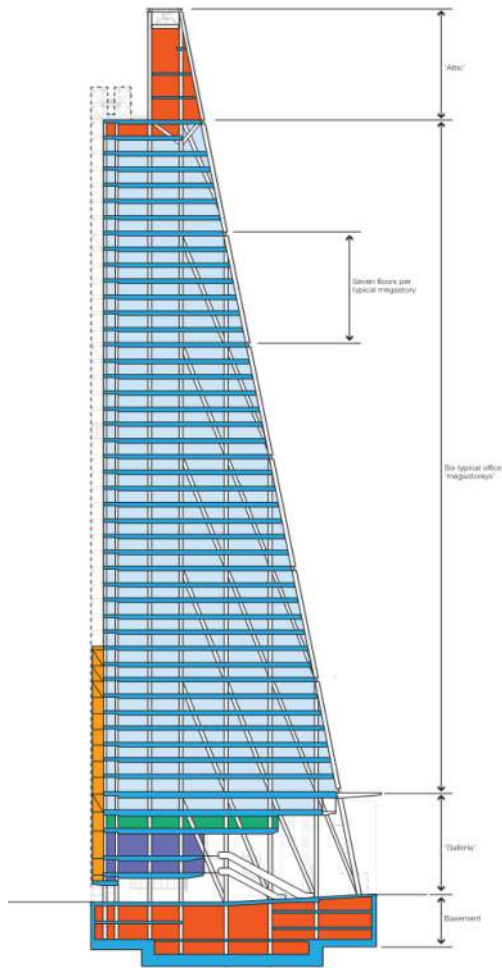
Efficiency and buildability

Managing movements

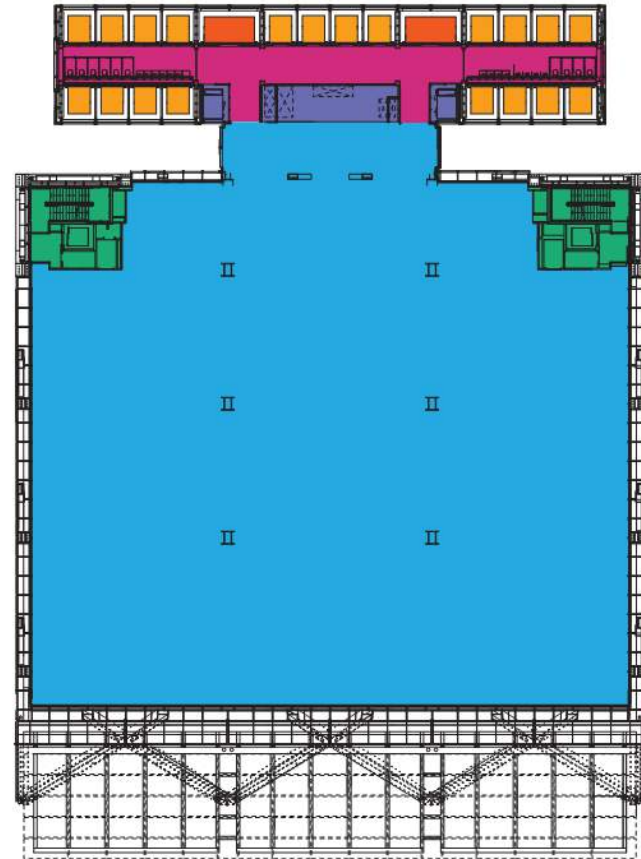
Lessons learned

The Leadenhall Building

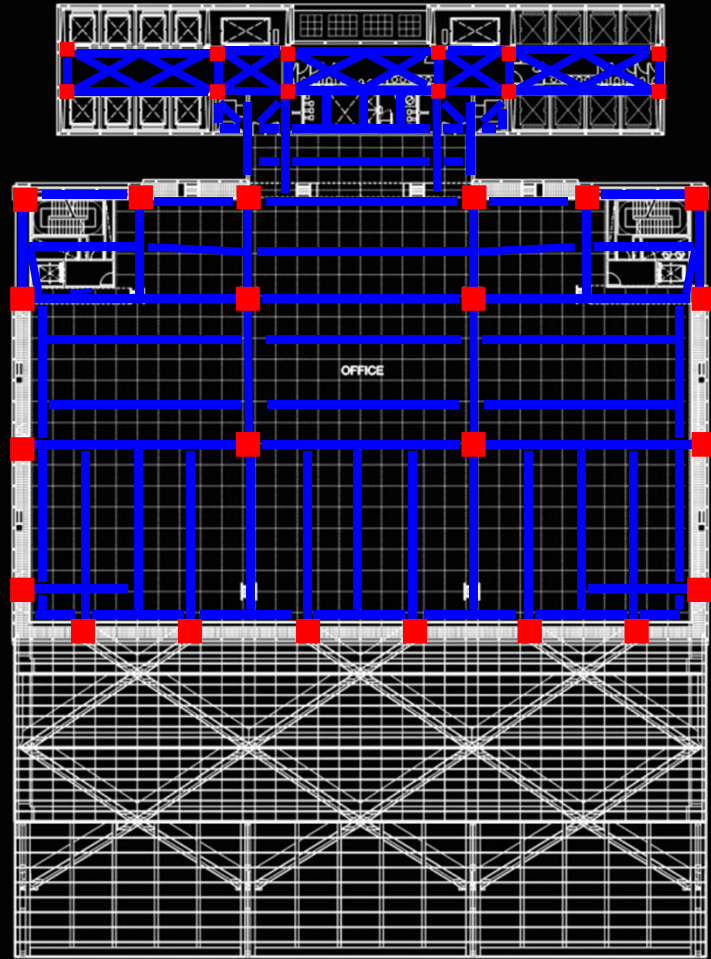
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- Office
- North core lobby/toilets
- East/west fire fighting cores
- On-floor plant and risers
- Passenger lifts
- Goods lifts



Building arrangement
ARUP



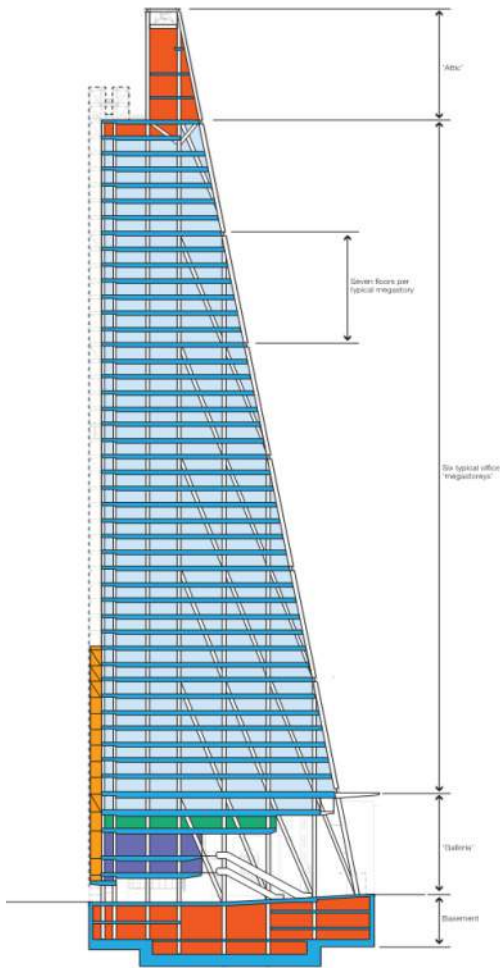
Floors

ARUP

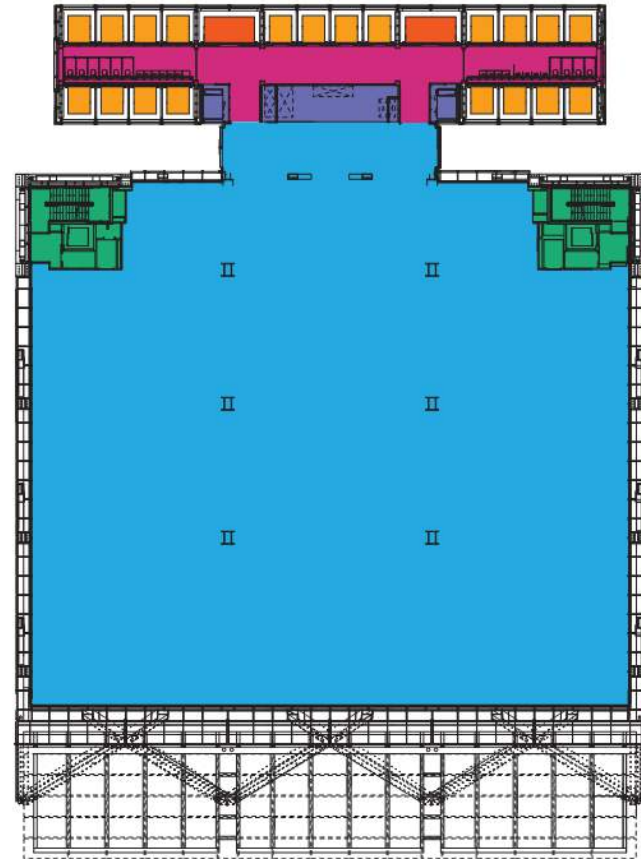


East and west fire fighting cores

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- Office
- North core lobby/toilets
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- On-floor plant and risers
- Passenger lifts
- Goods lifts

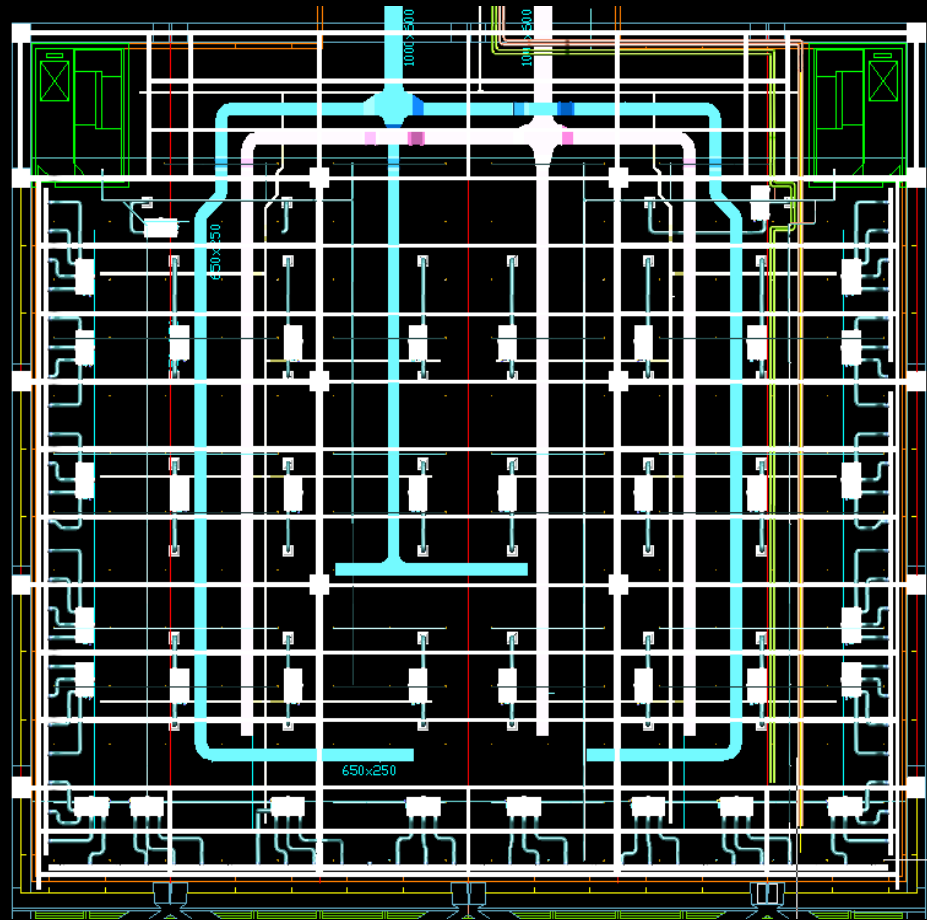
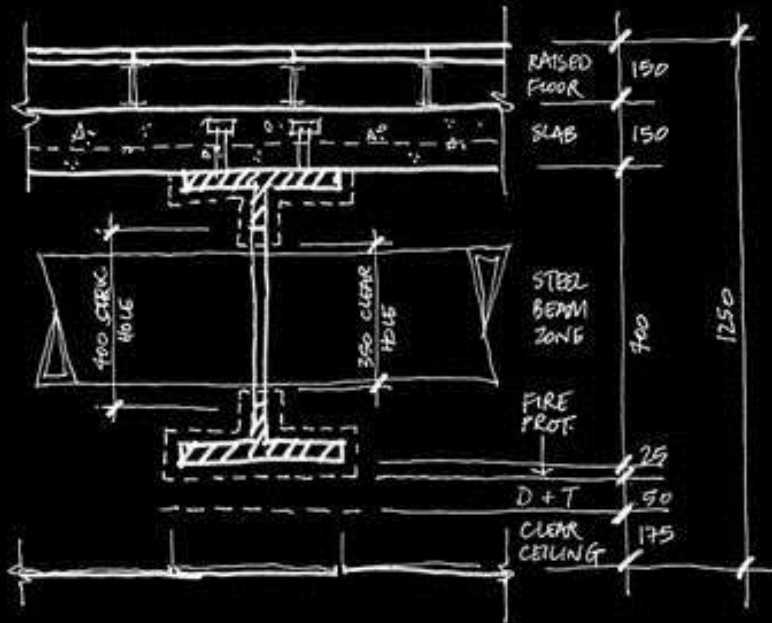


Building arrangement



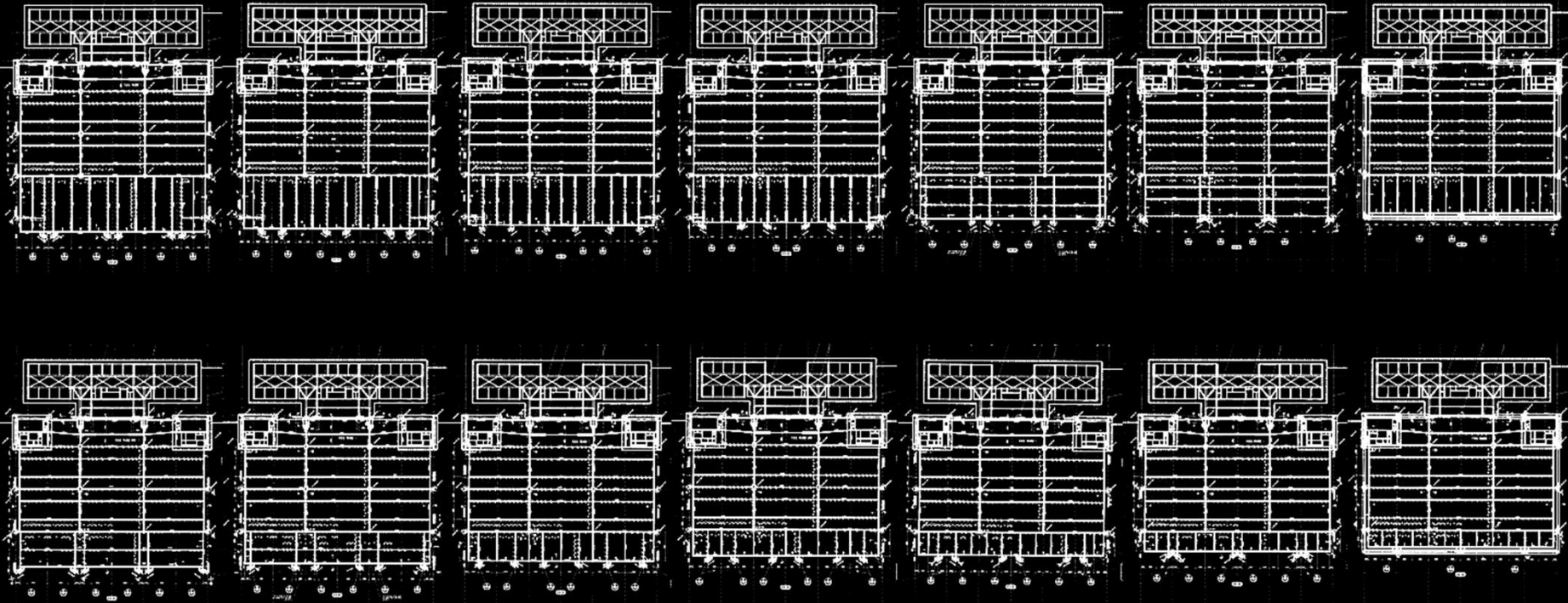
On-floor services

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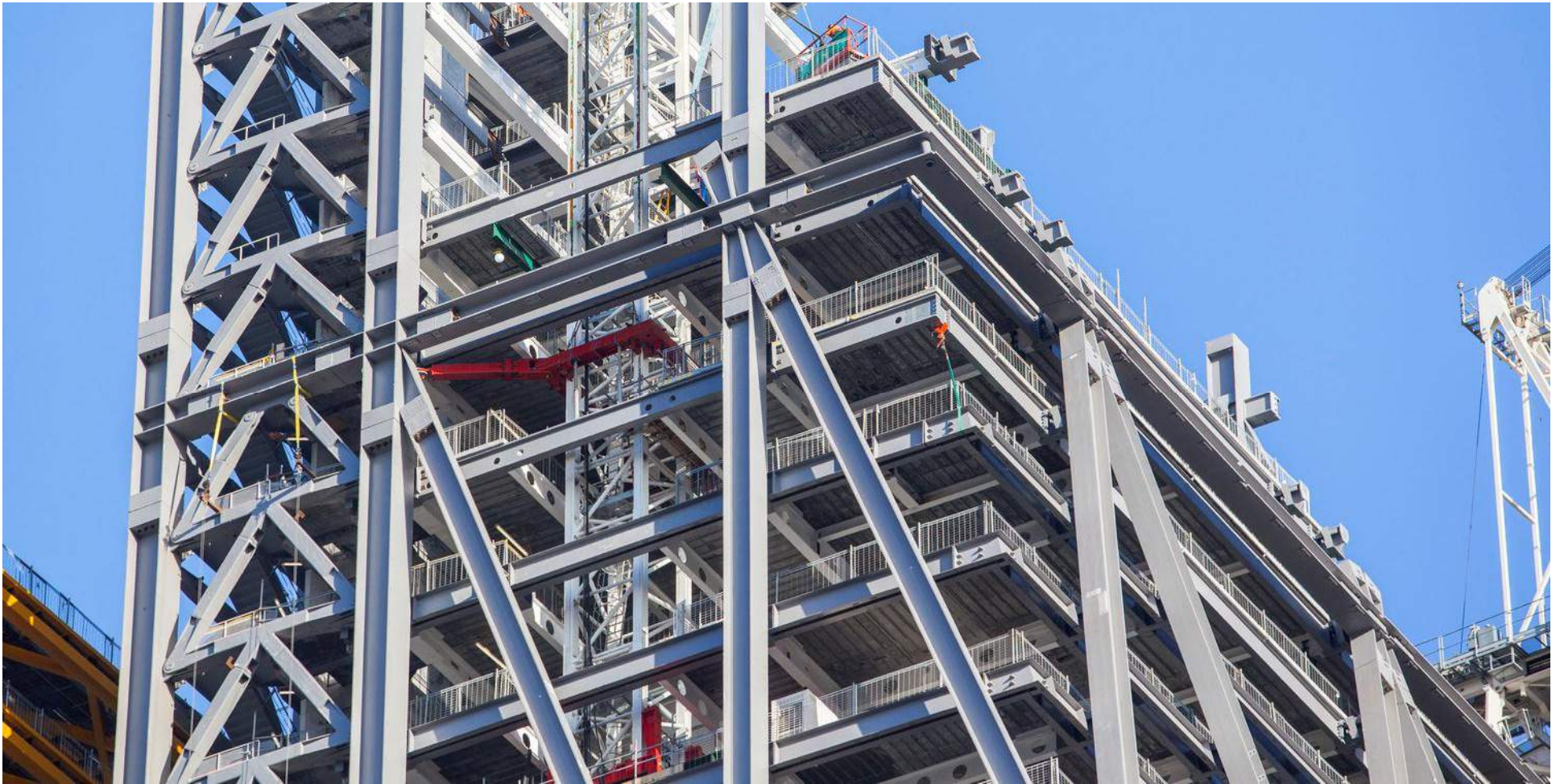
Floors

ARUP



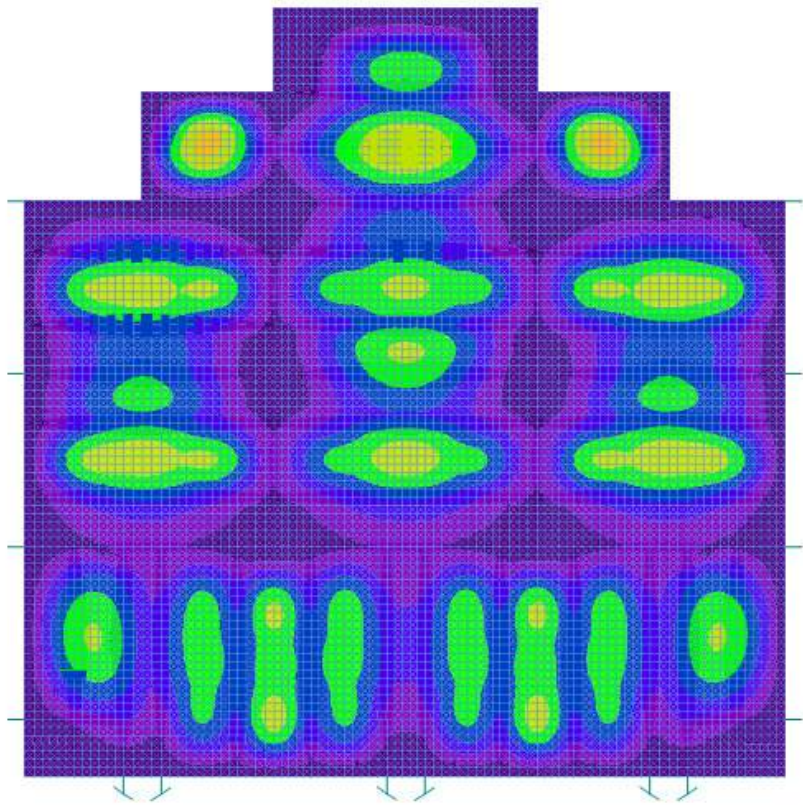
Floors

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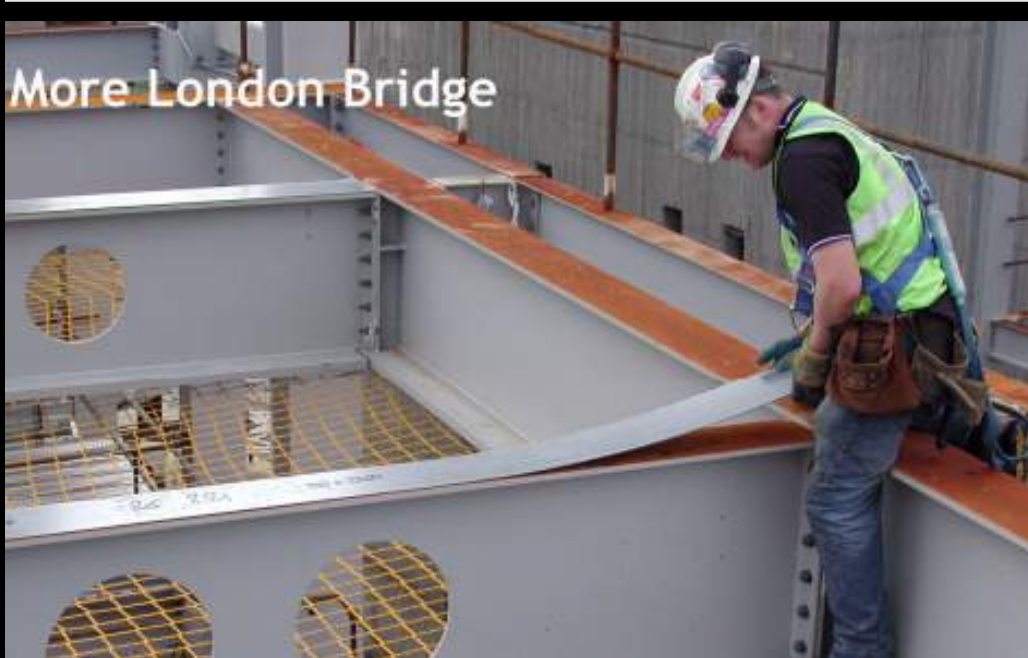
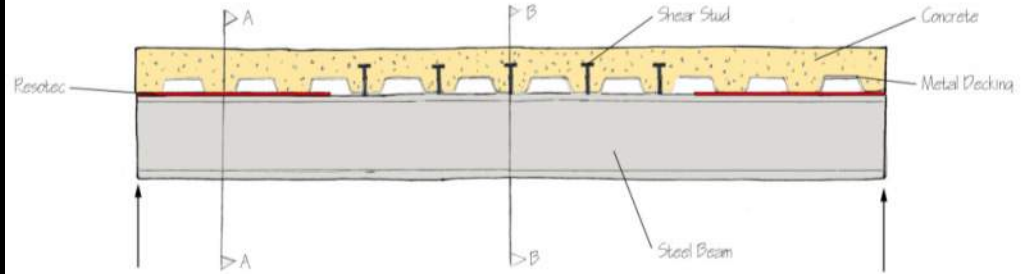


Floors

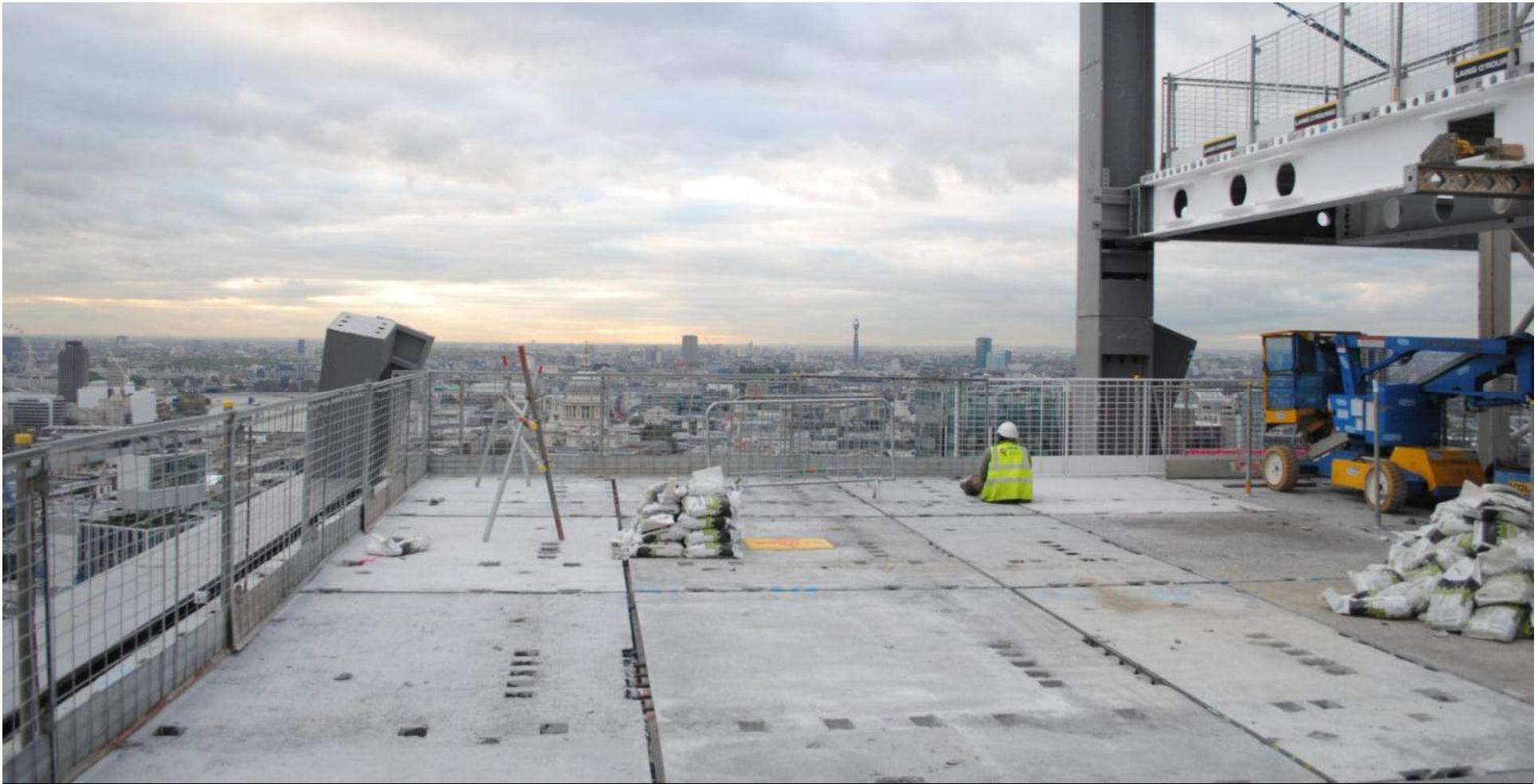
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Floors

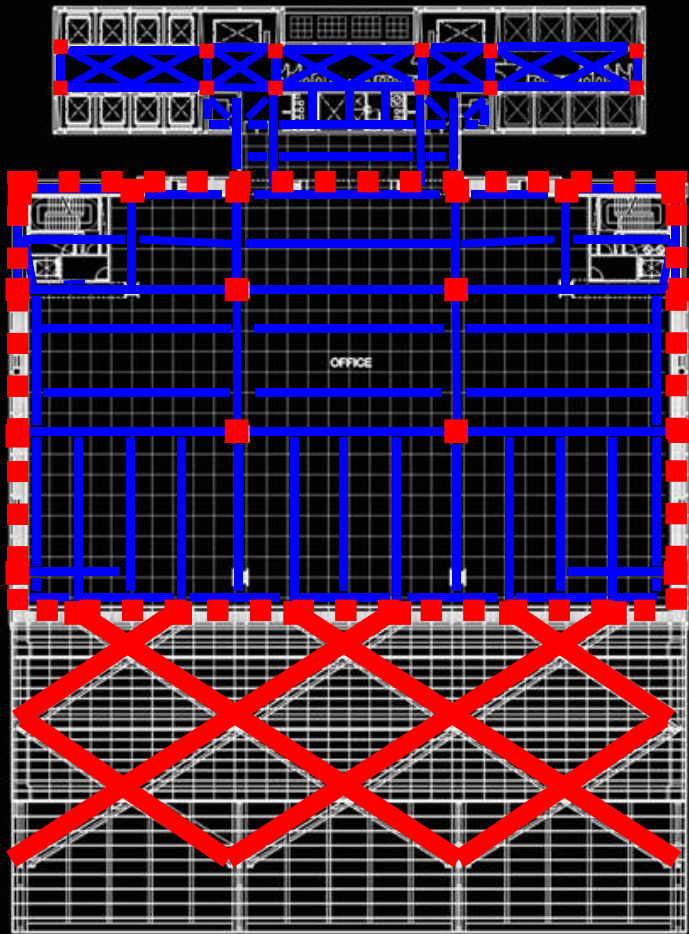


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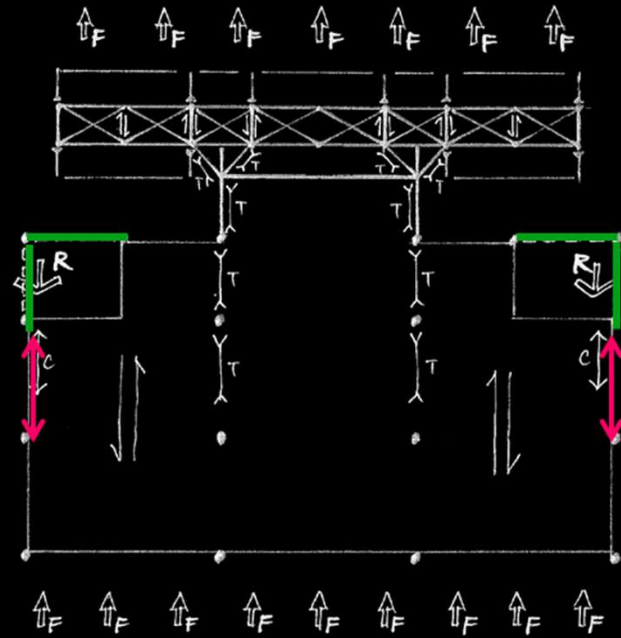
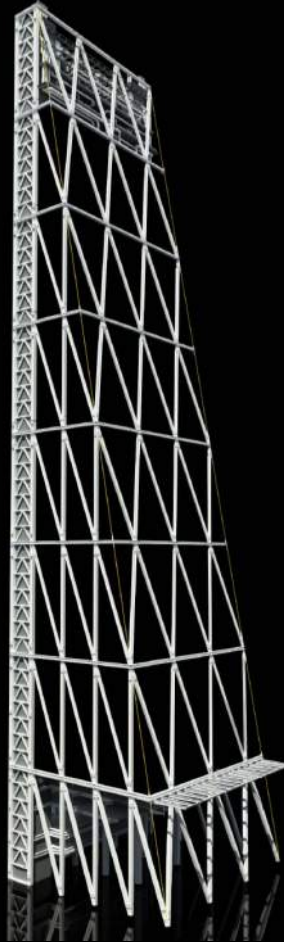


Floors

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Stability system



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Cooling towers

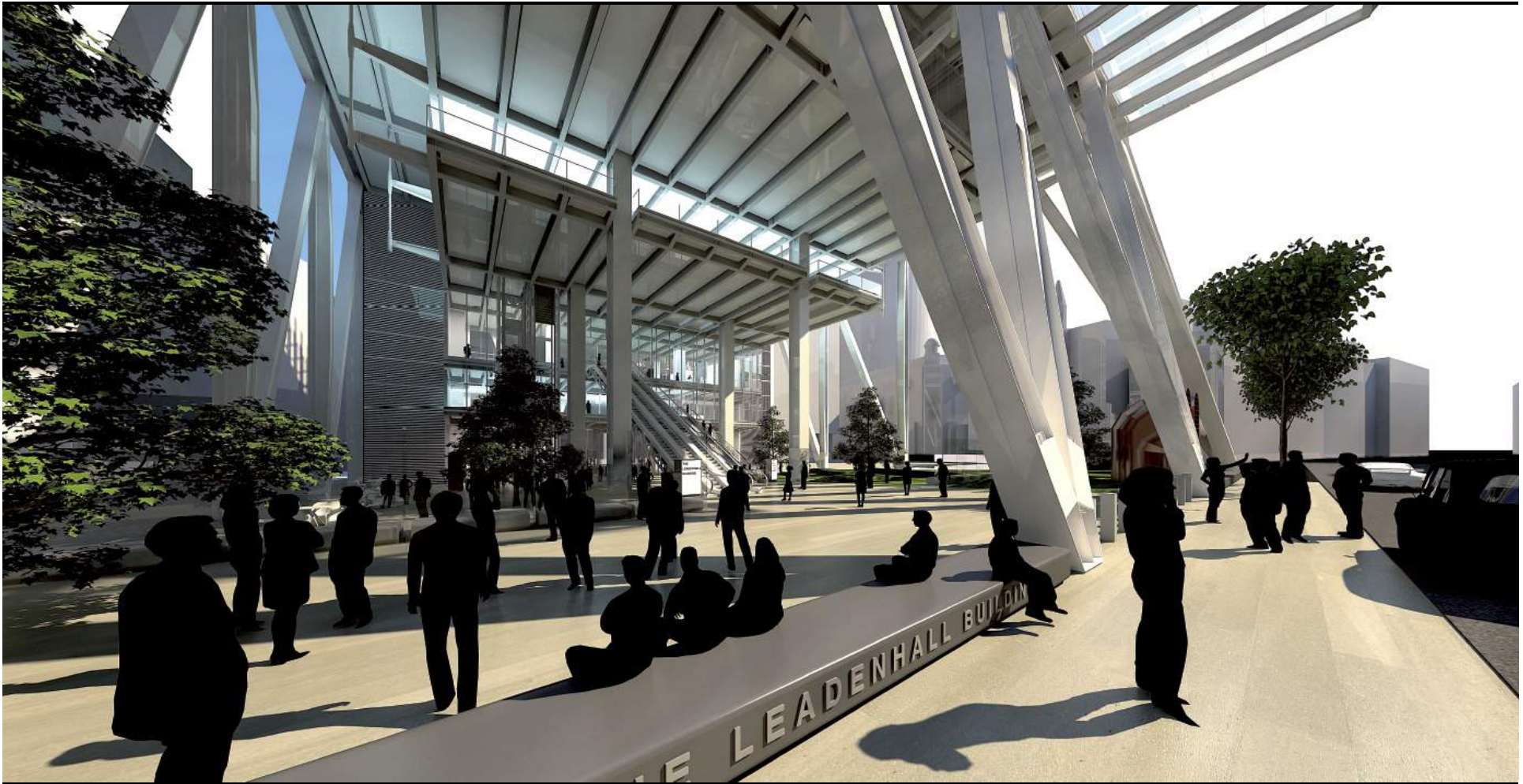
Generators

Boilers

Attic

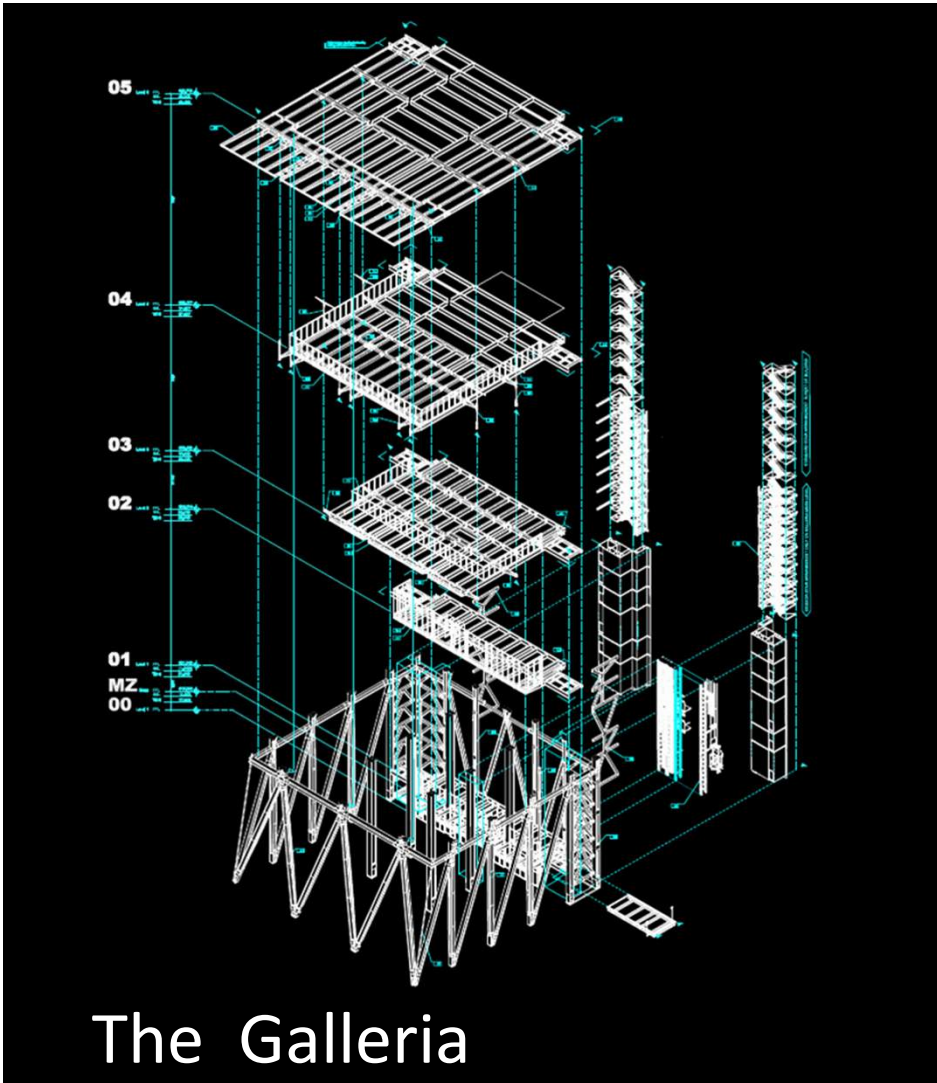


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The Galleria

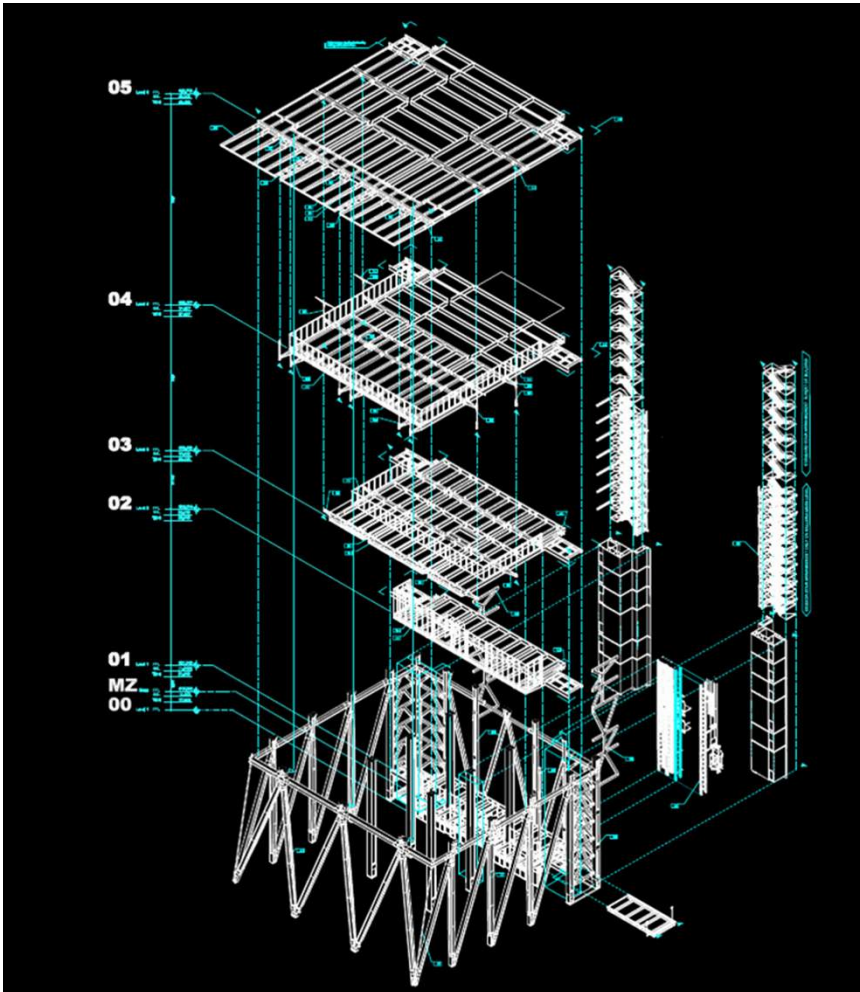
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The Galleria



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The Galleria

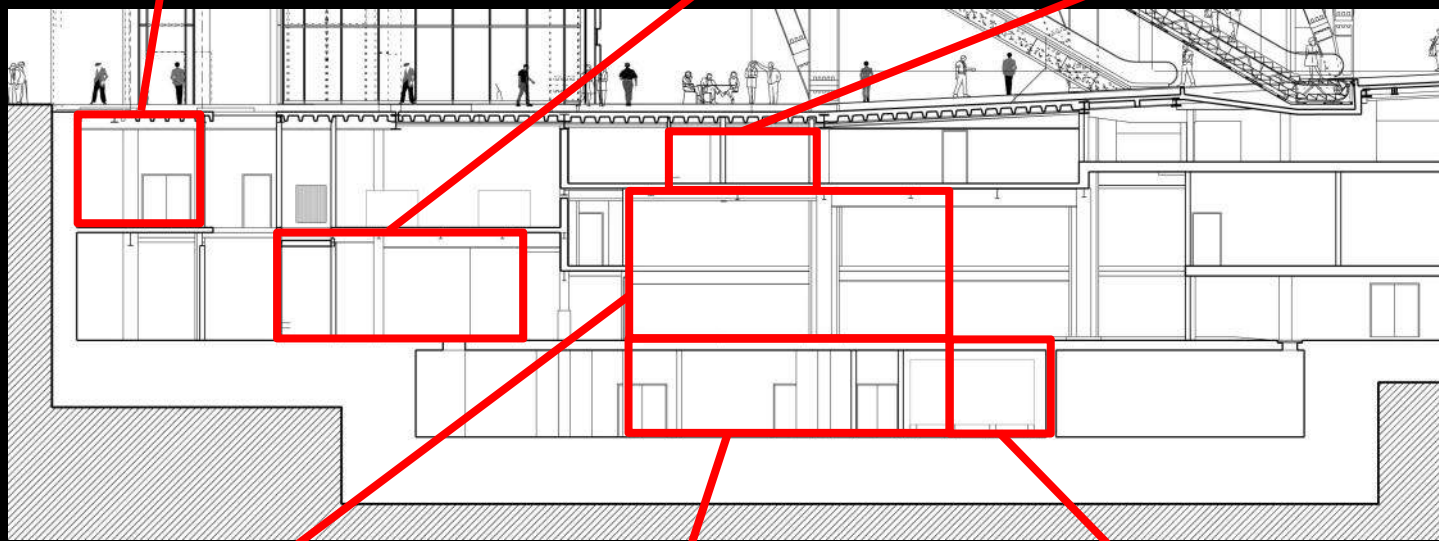


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Basement supply and
extract

Future tenant
generators

Loading bay
extract



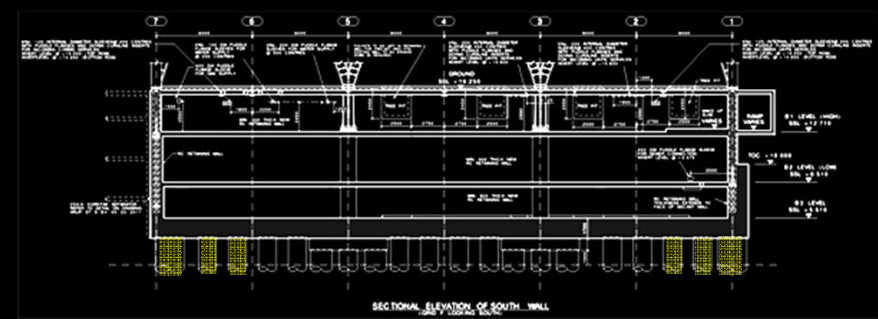
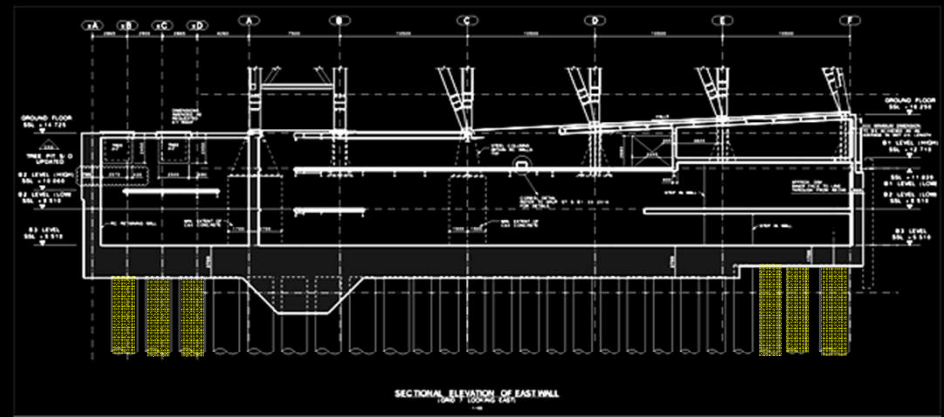
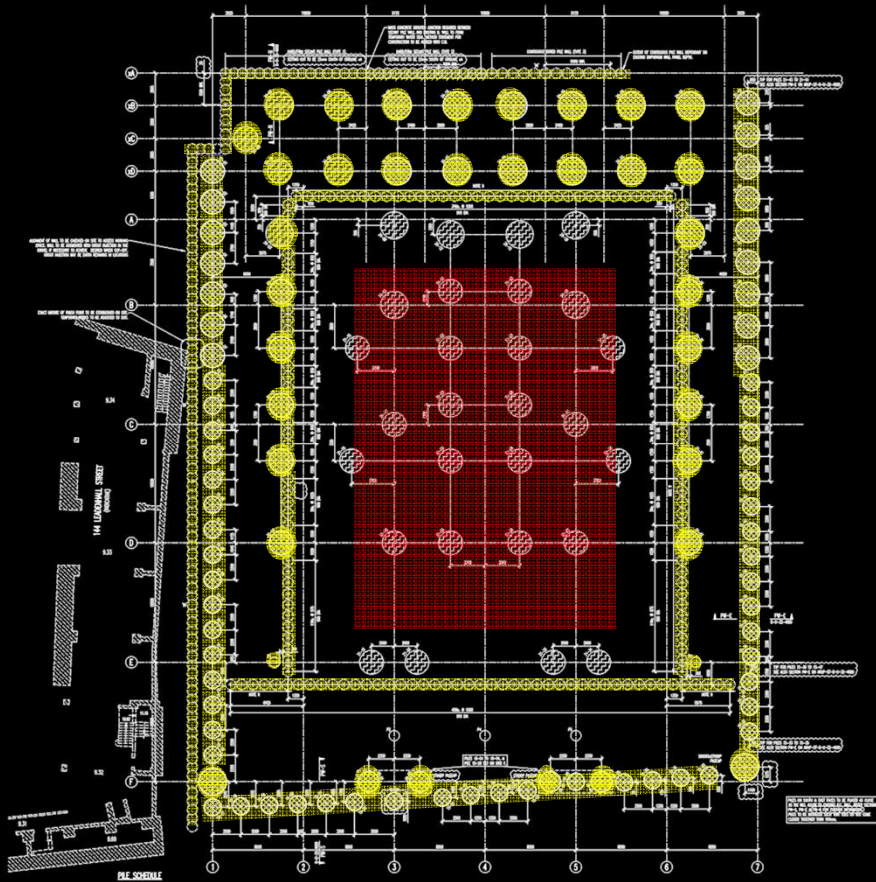
Landlord
chillers

Future tenant chillers

Sprinkler and diesel
tanks

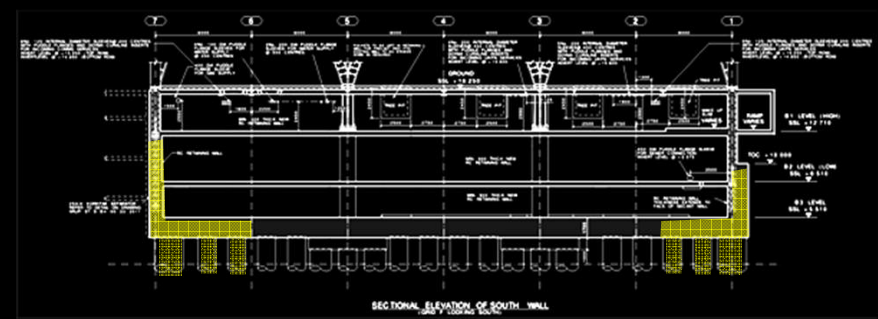
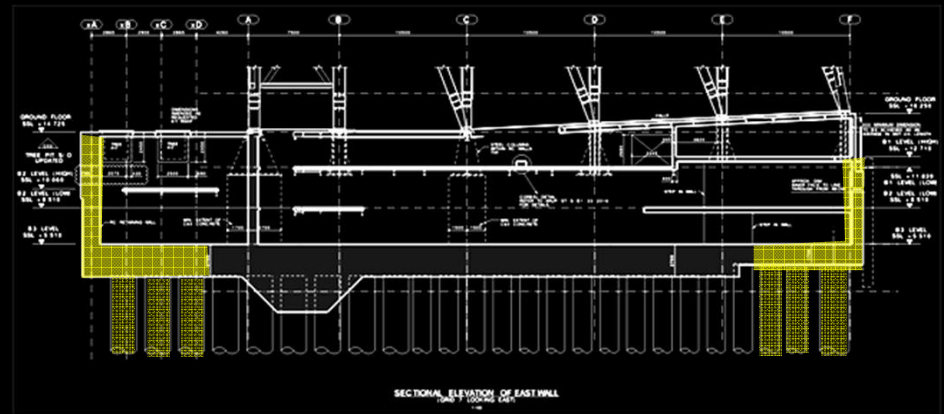
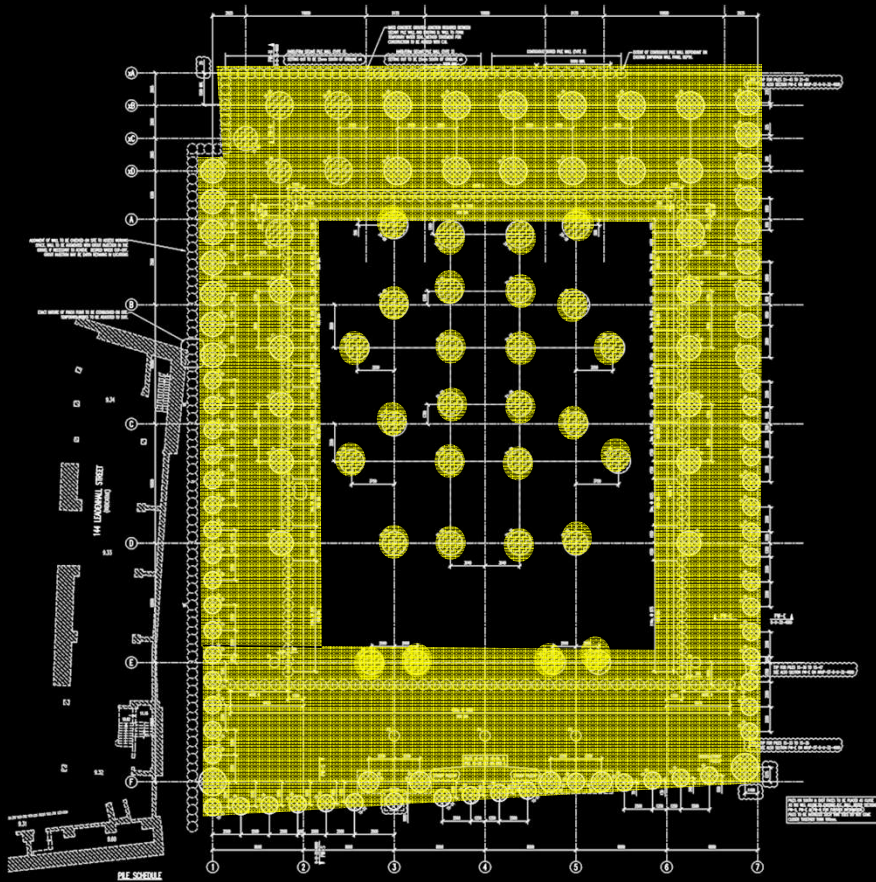
Basement

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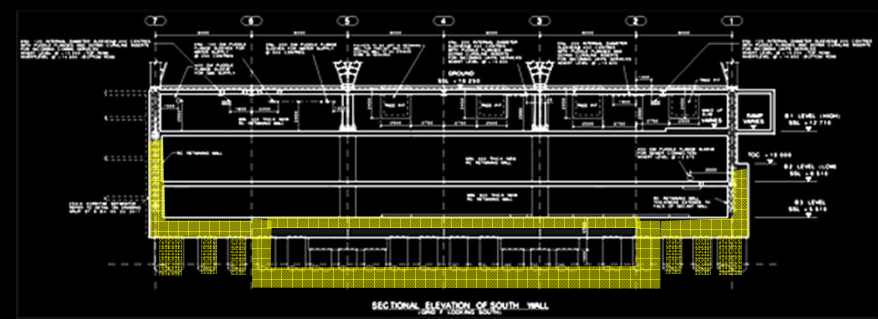
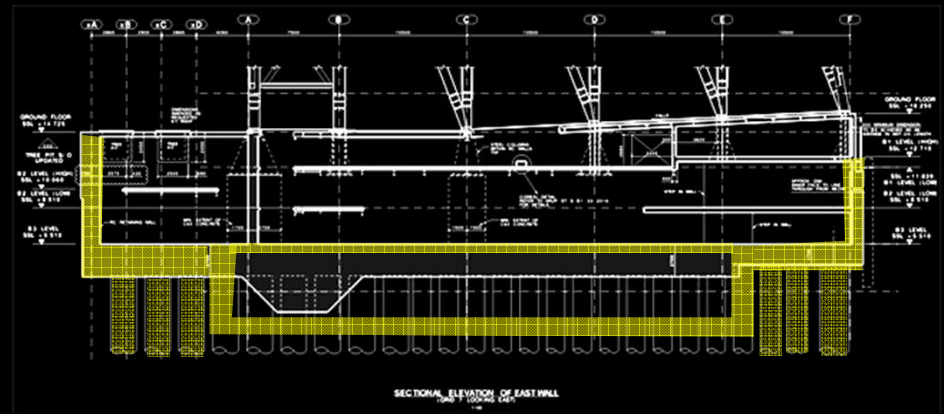
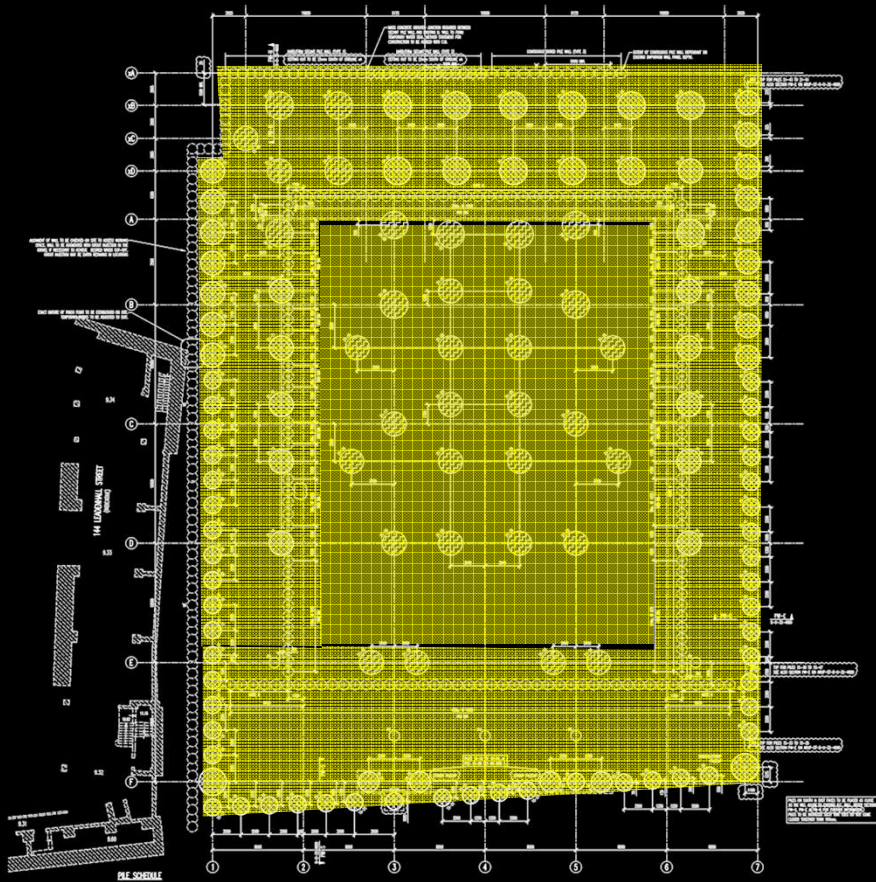
Basement and Foundations





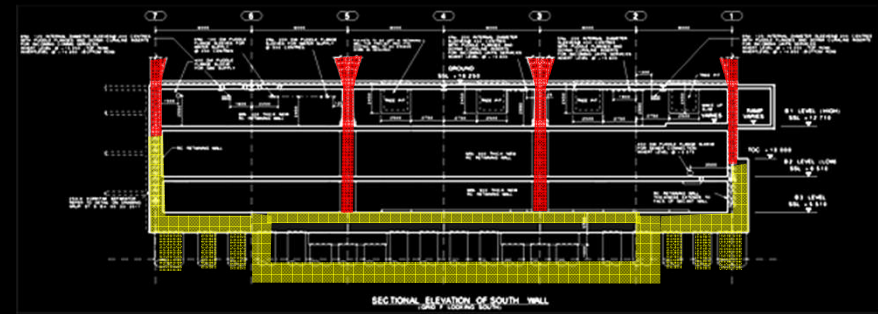
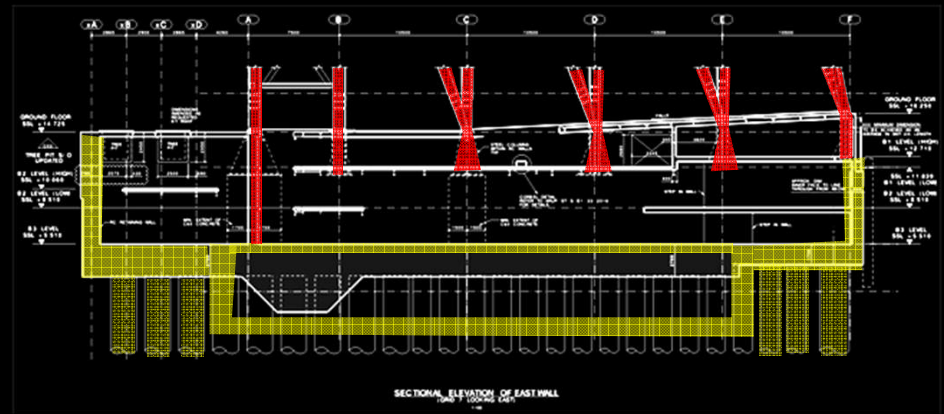
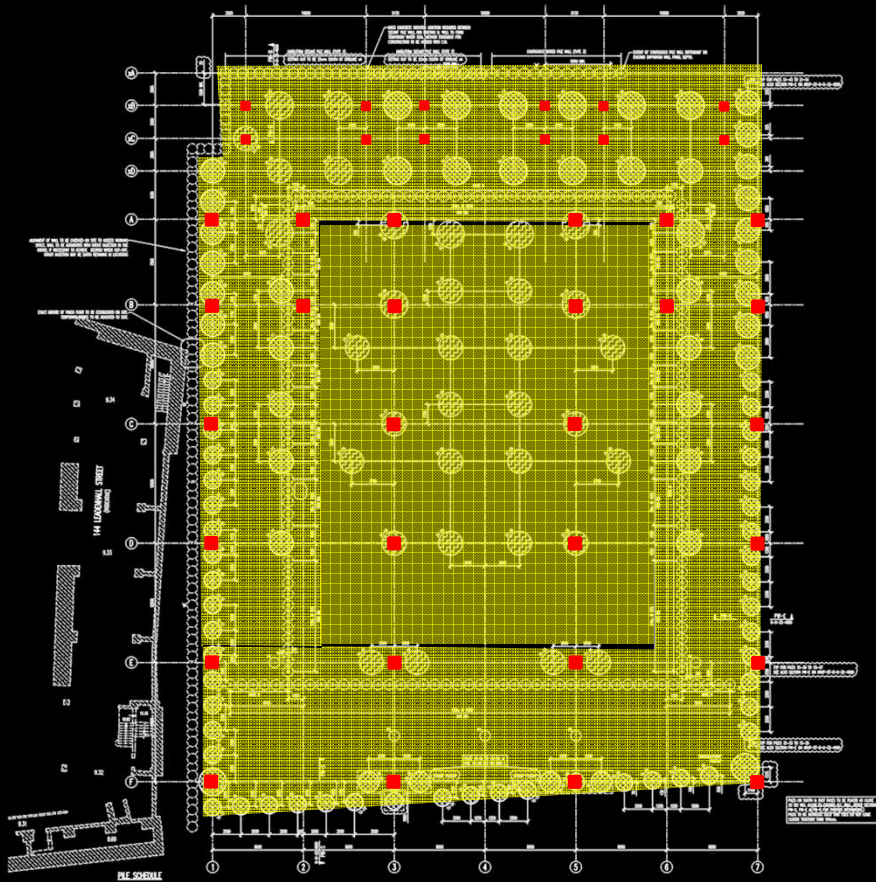
Basement and Foundations

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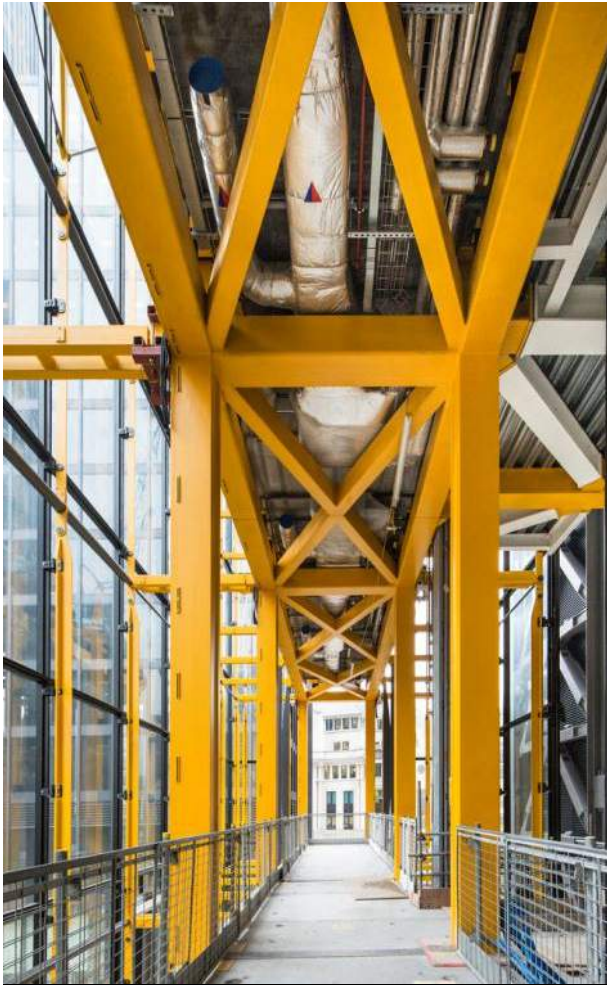
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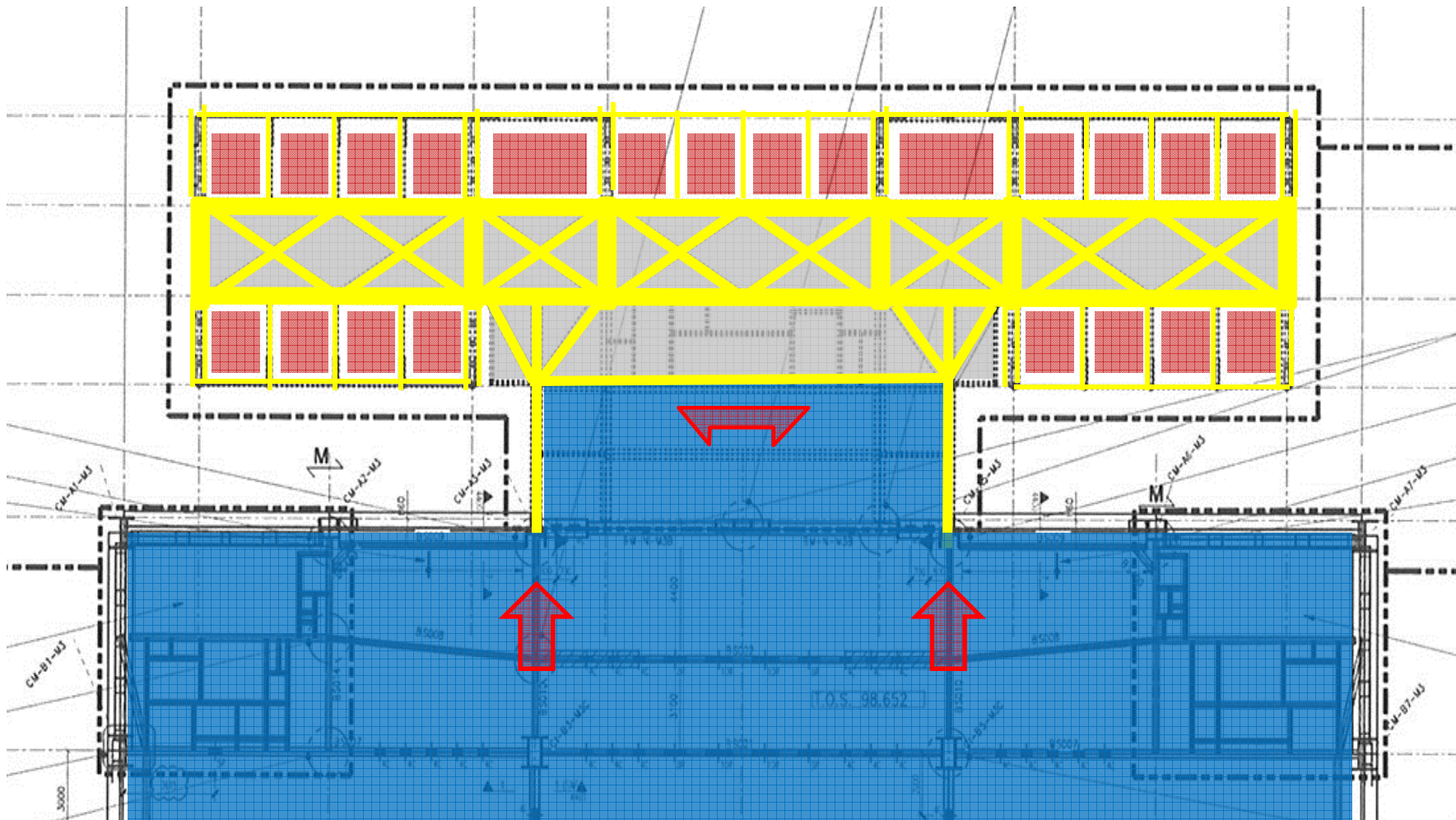
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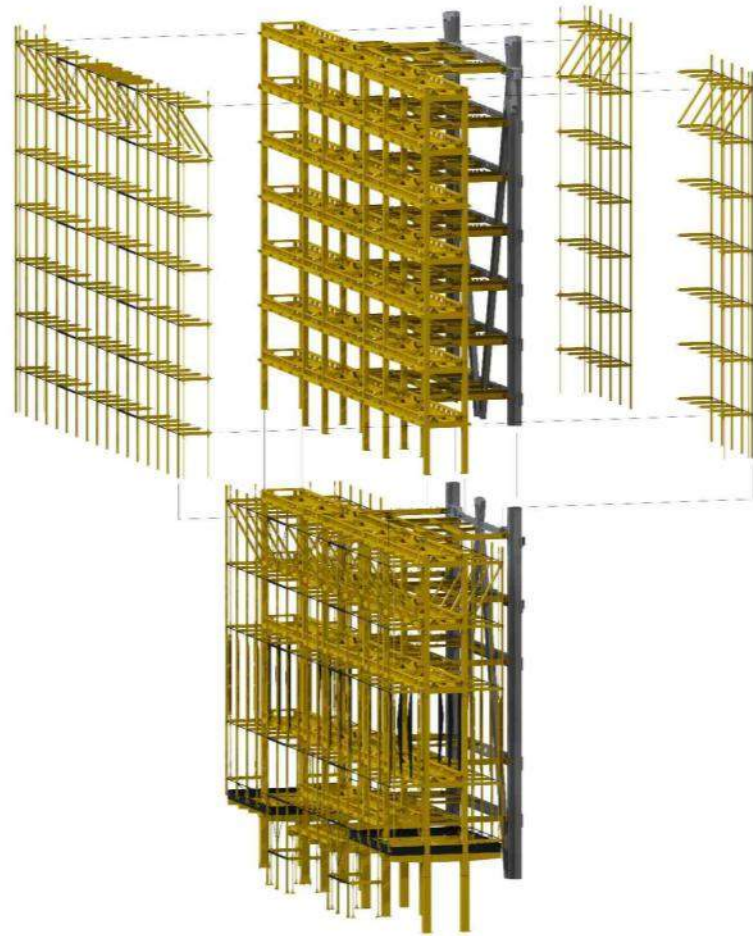
The North Core



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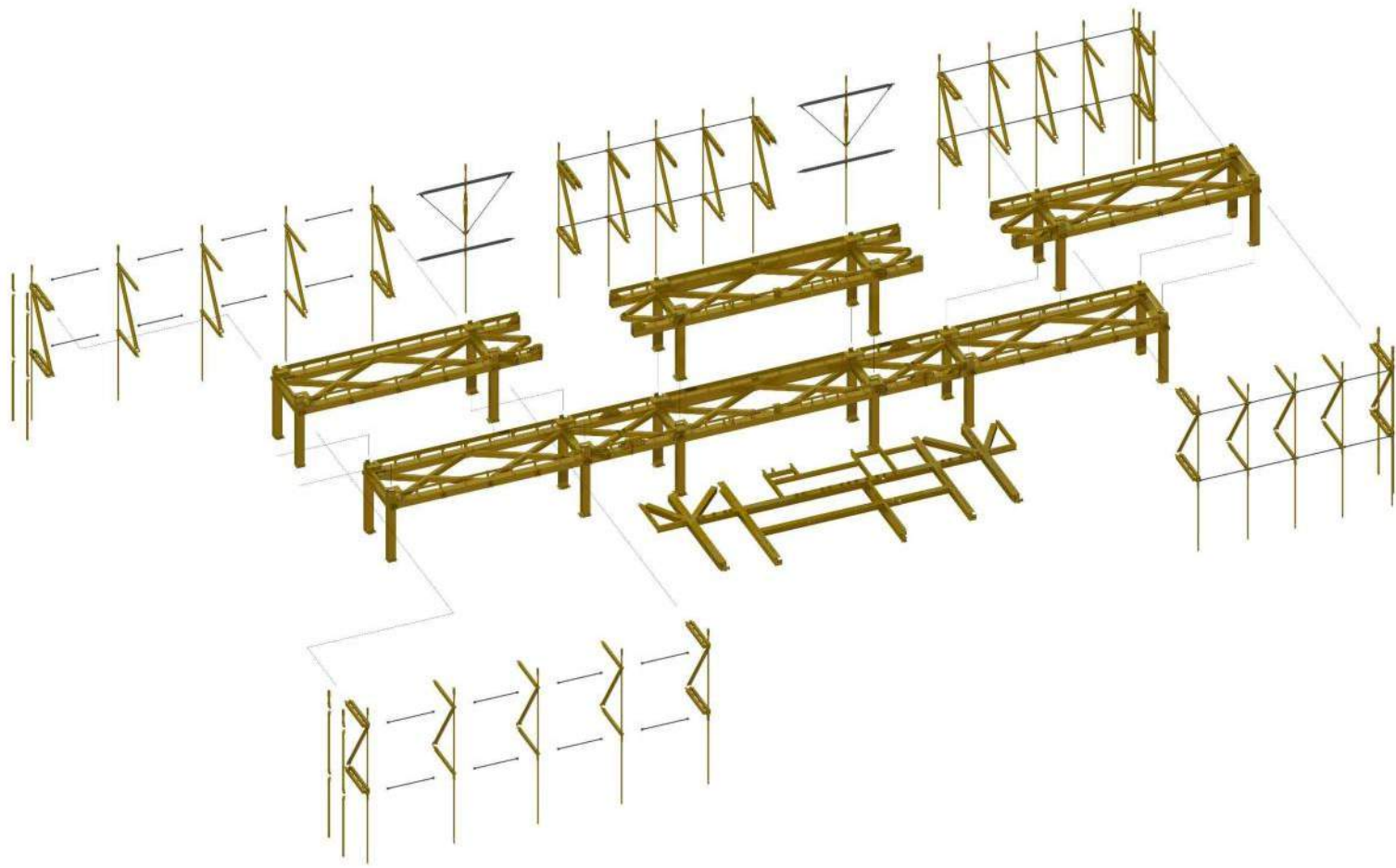


The North Core



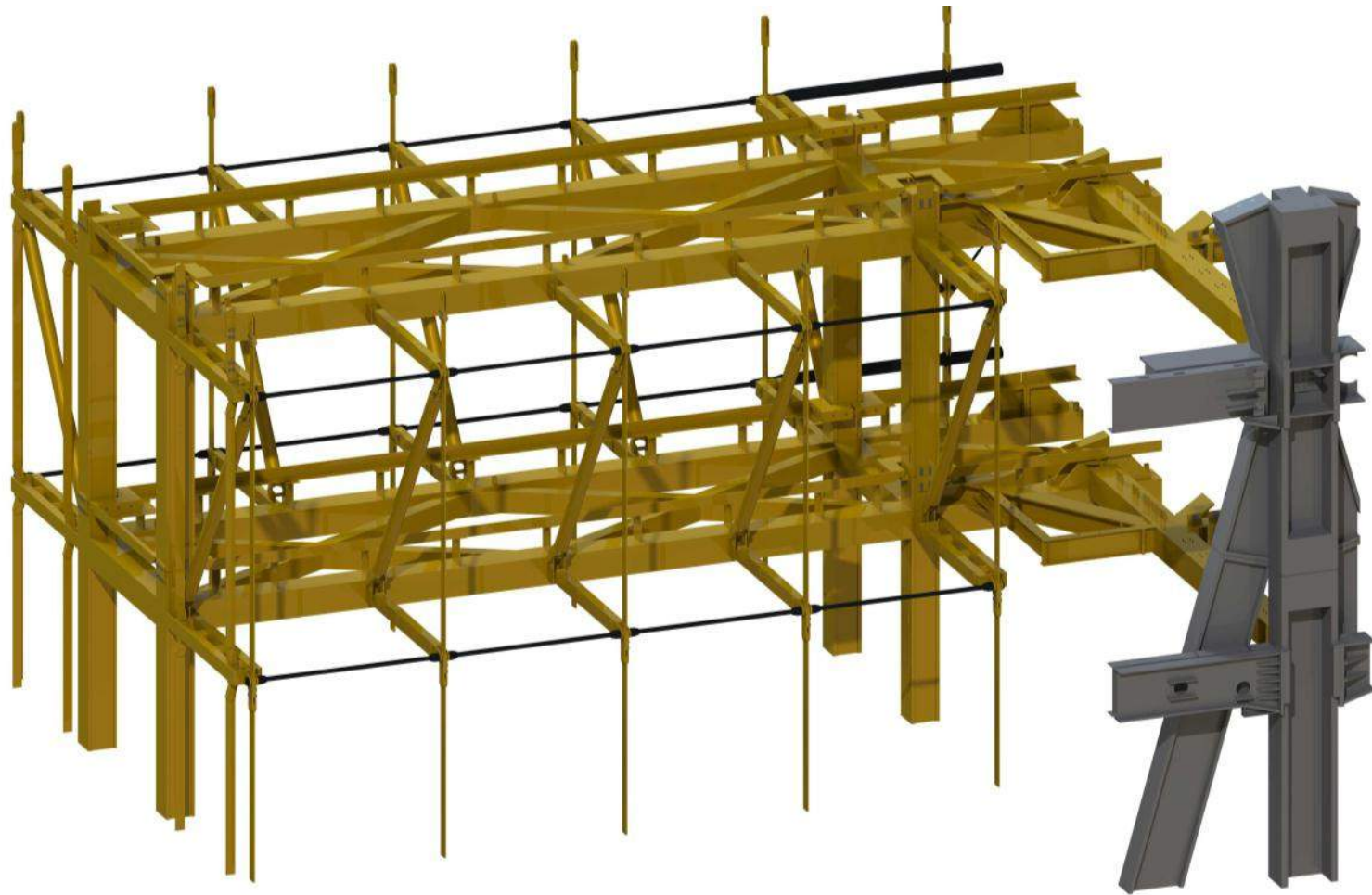
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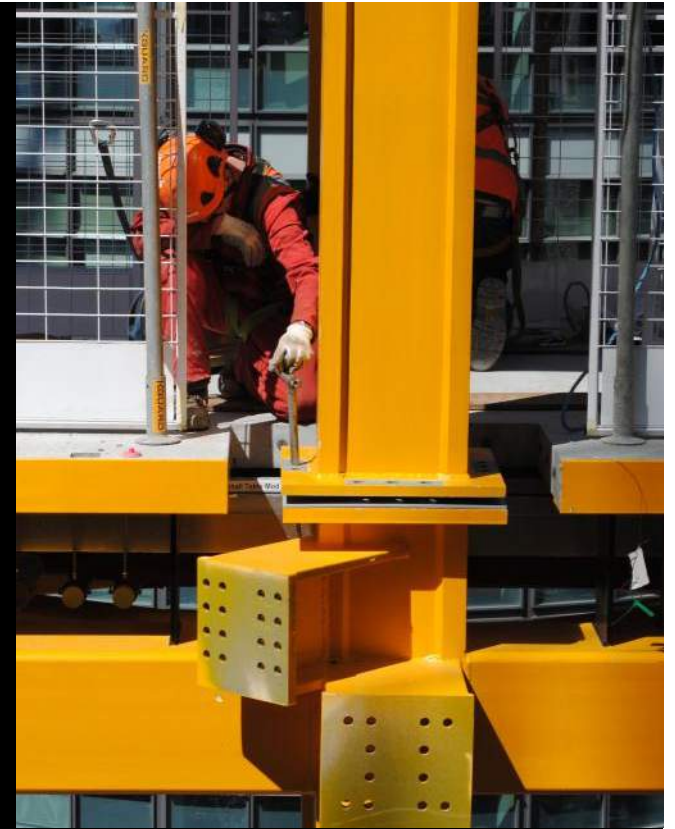
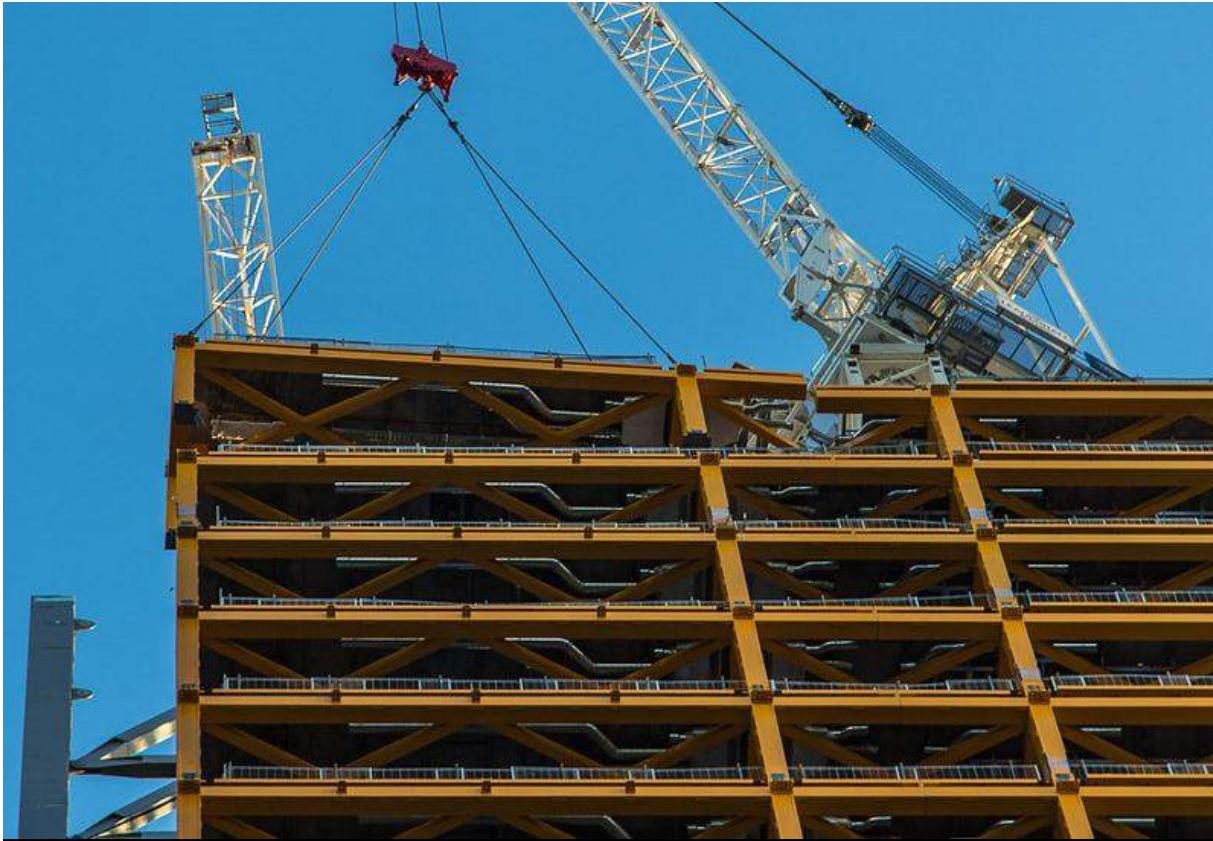
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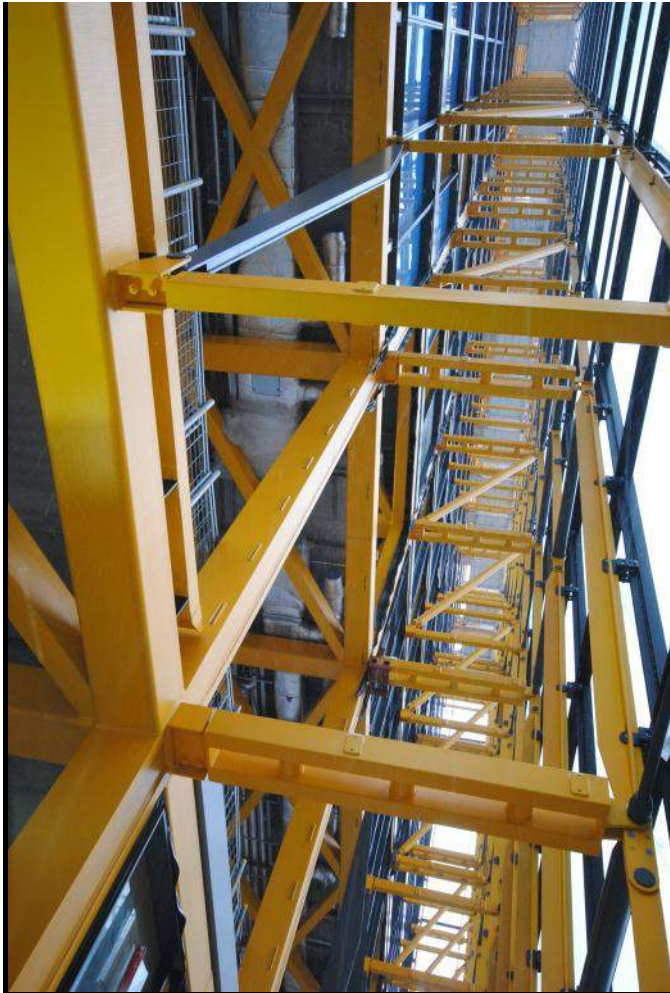
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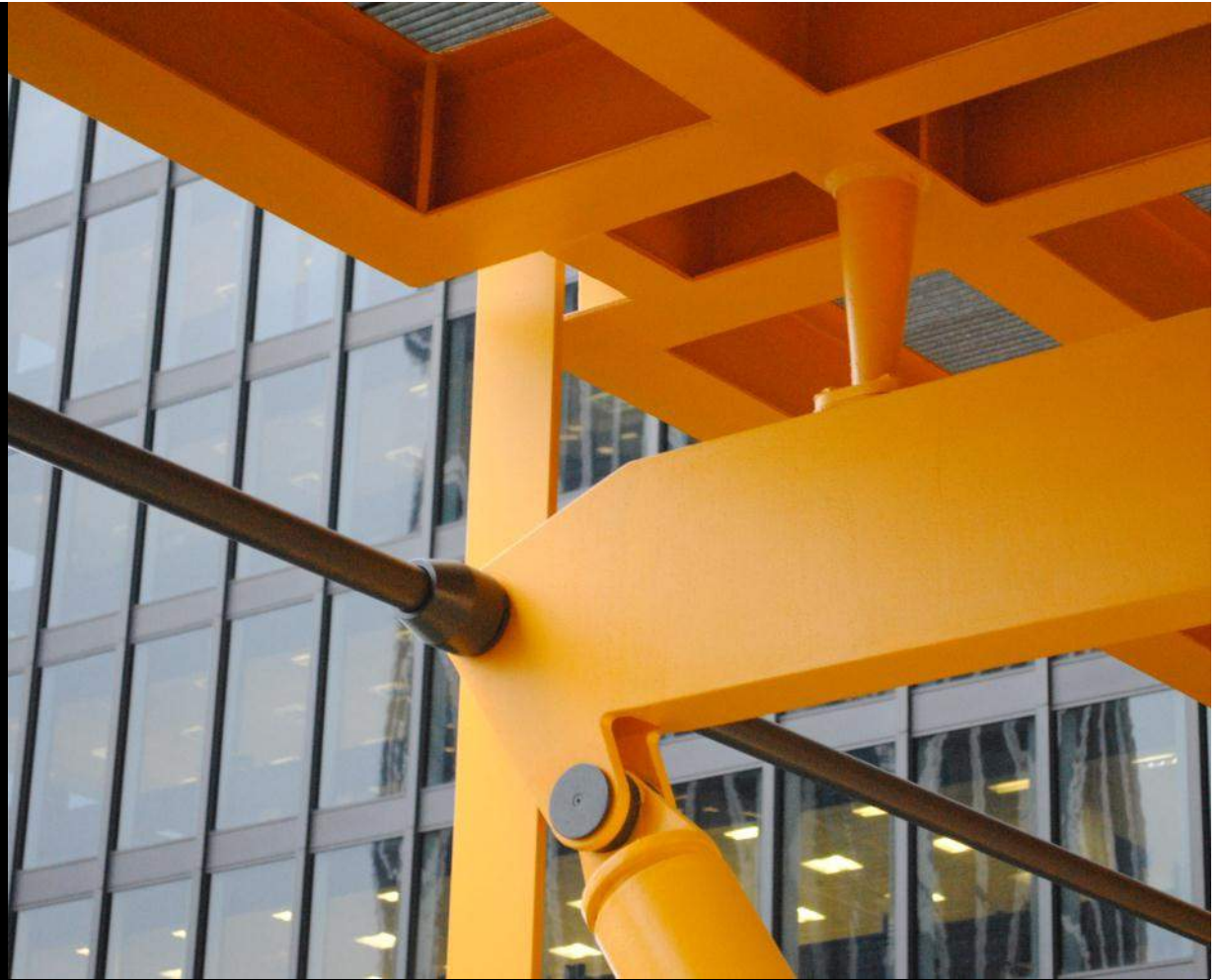


The North Core

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The North Core



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Lessons learned

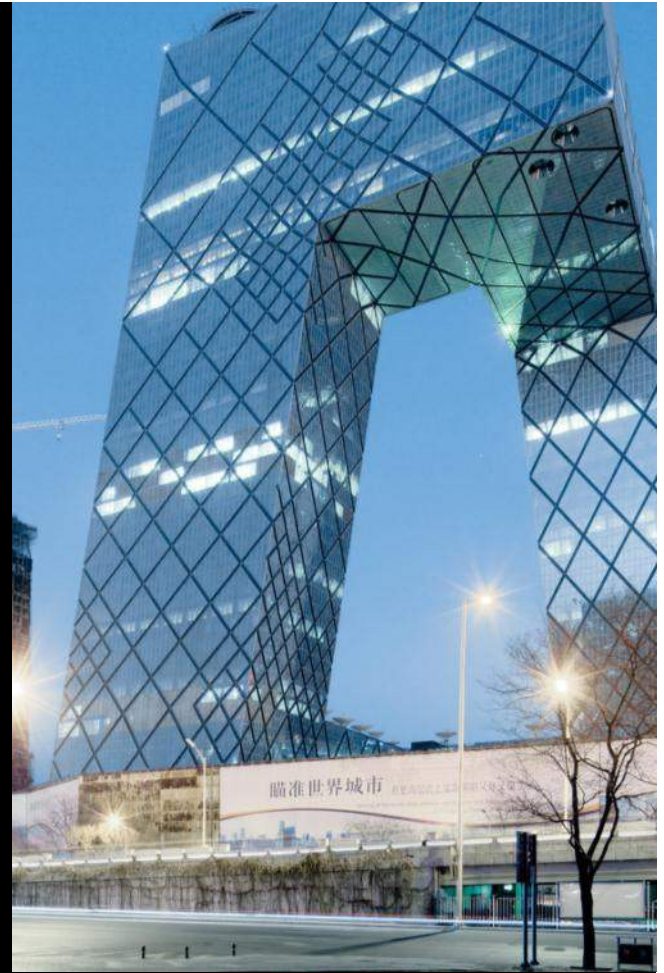
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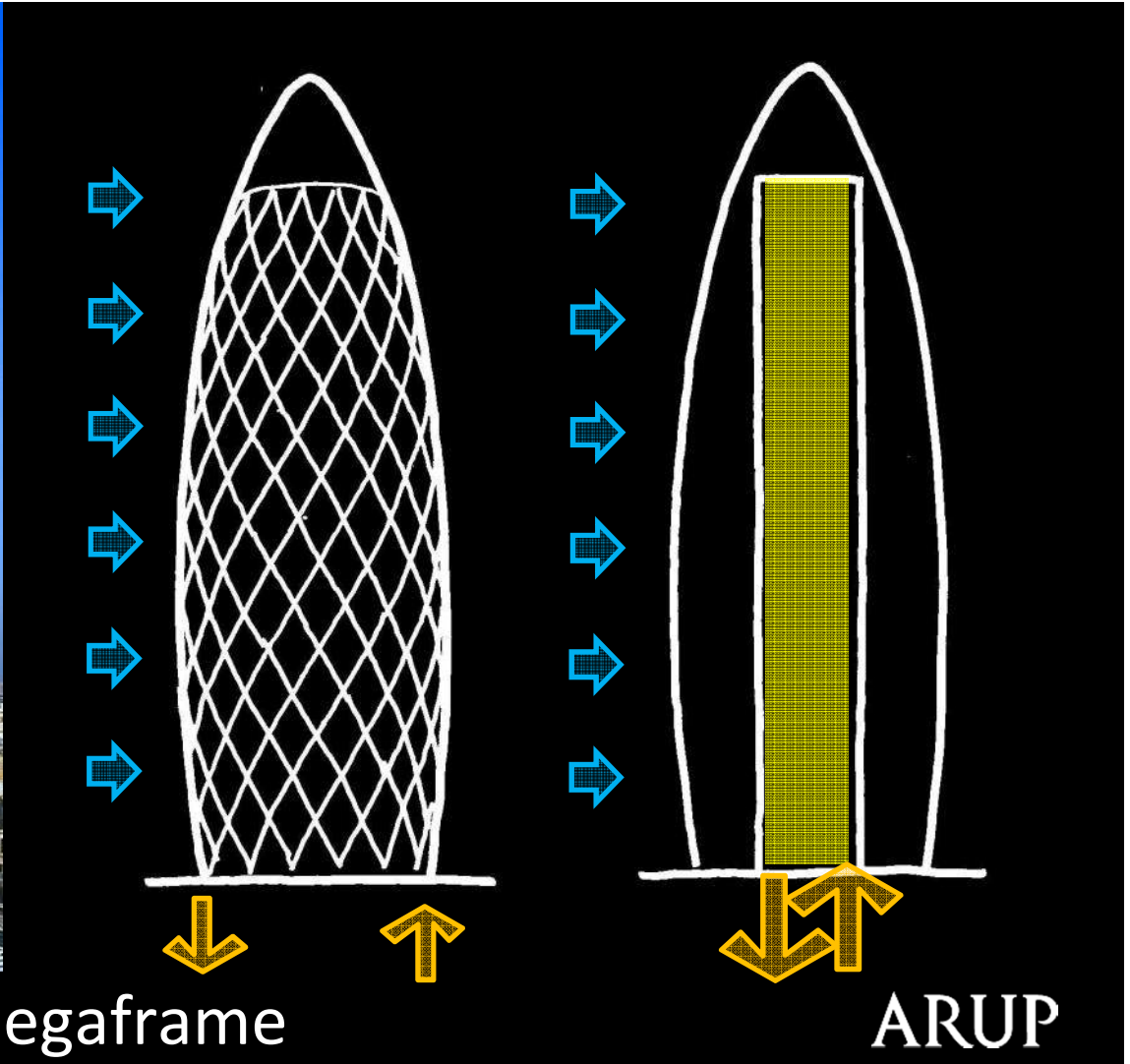
The challenge of the megaframe

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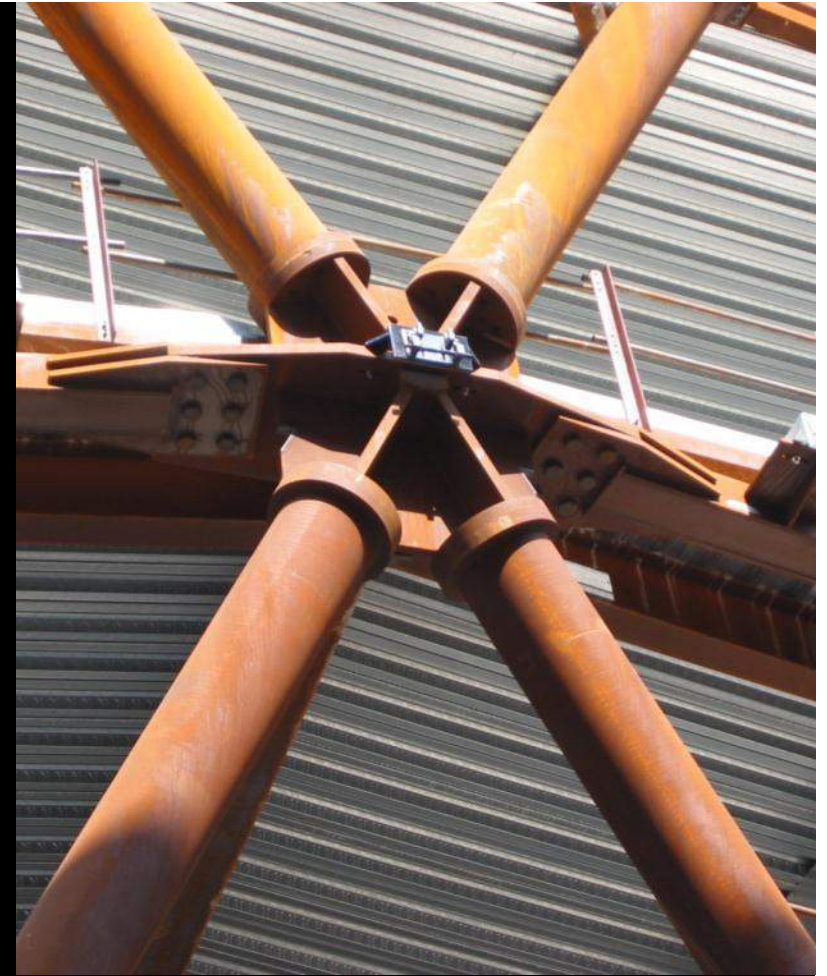
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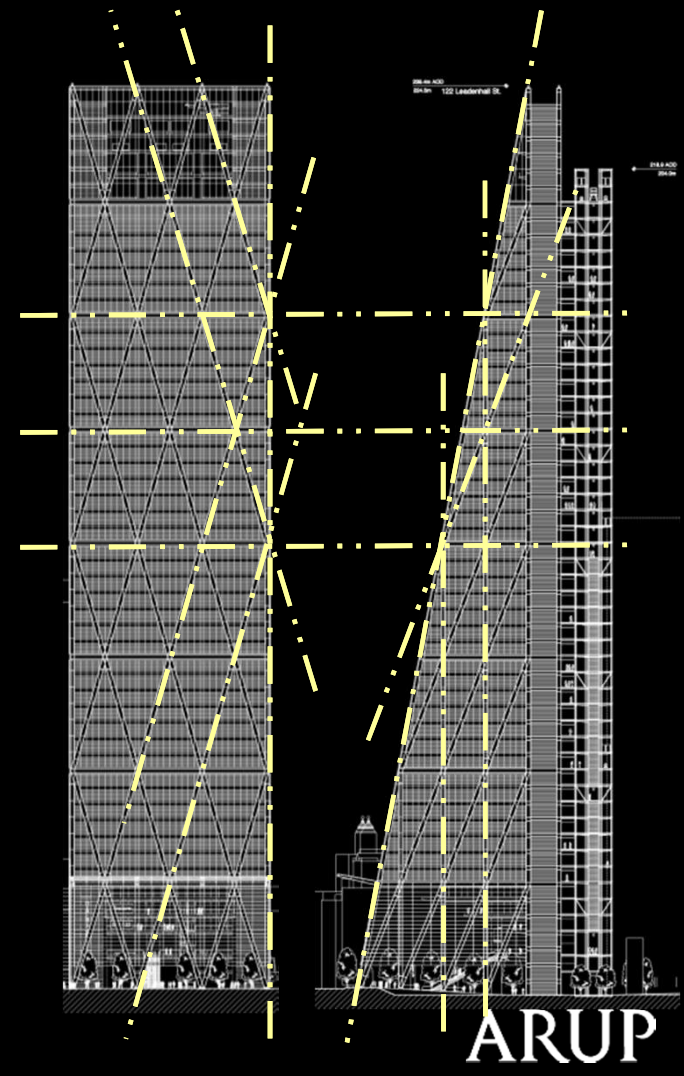
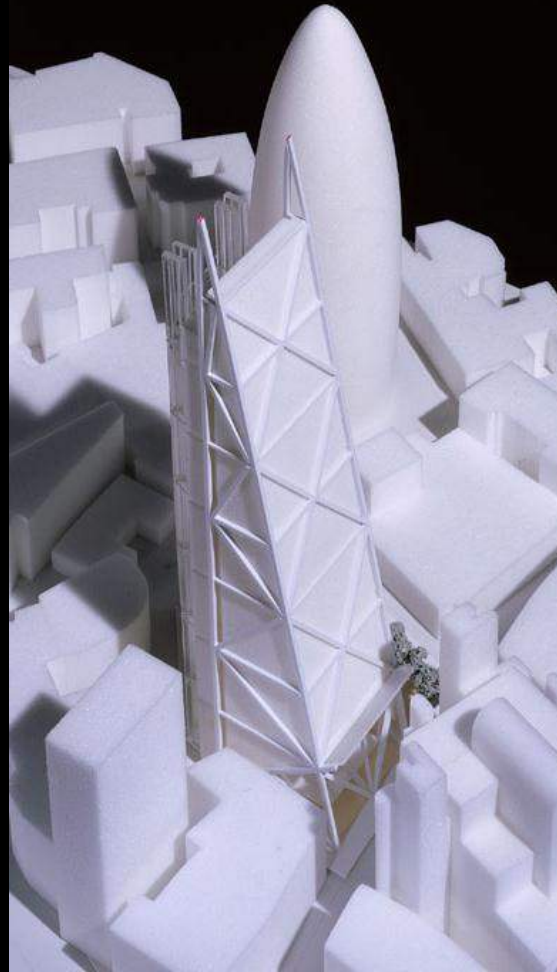
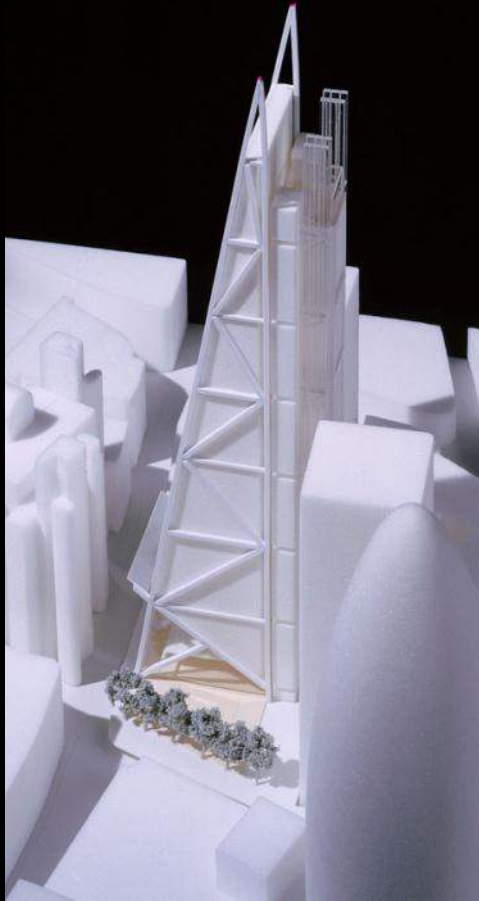
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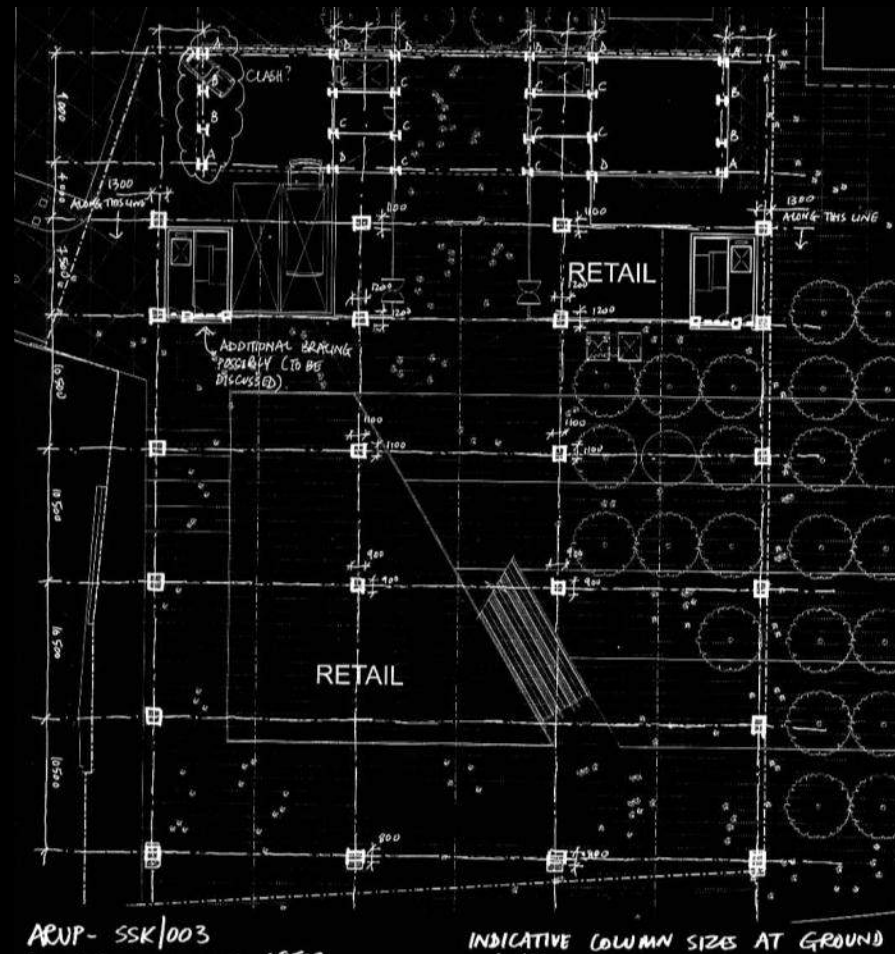


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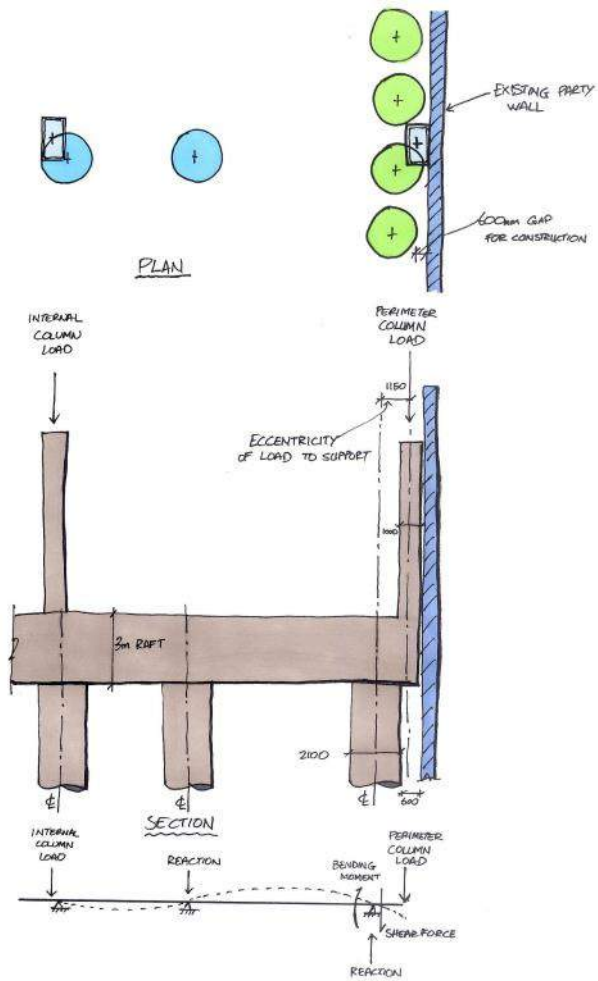


The challenge of the megaframe



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Basement and Foundations

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The challenge of the megaframe

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The challenge of the megaframe

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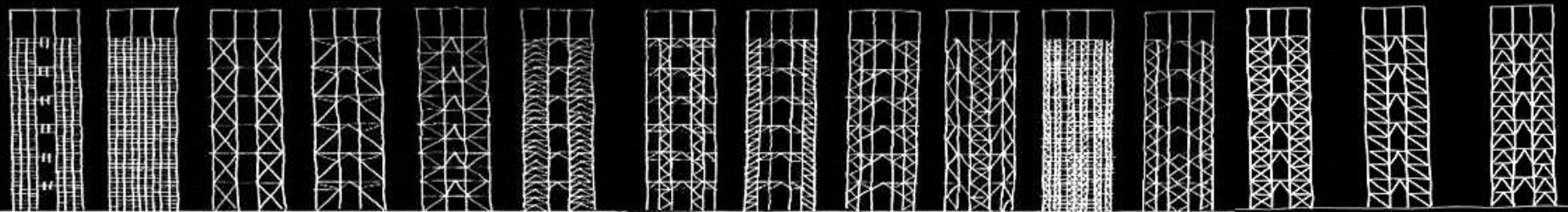
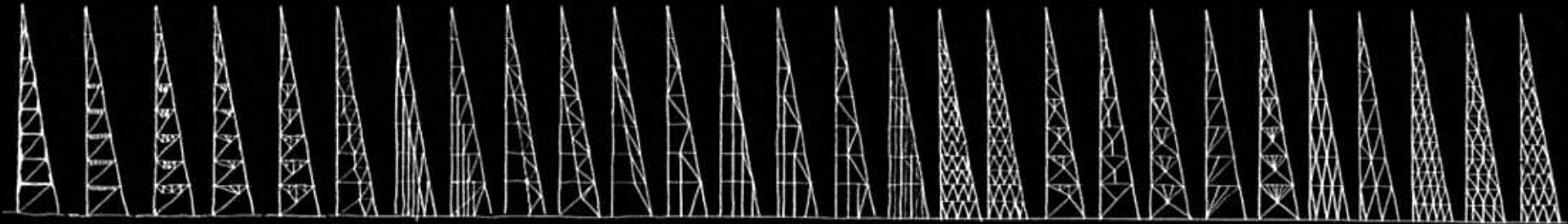
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Design drivers

- Material efficiency
- Programme
- Simplicity
- Visual consistency

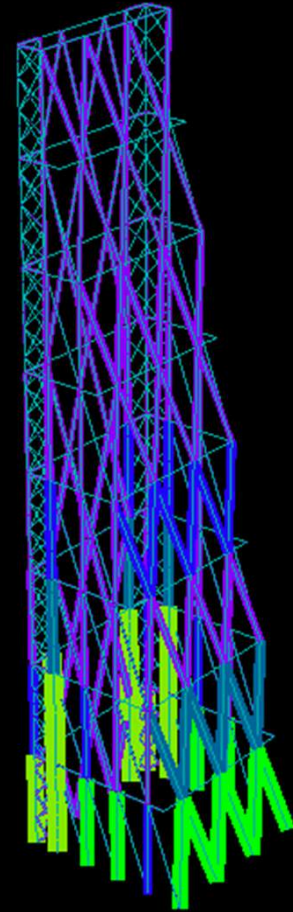
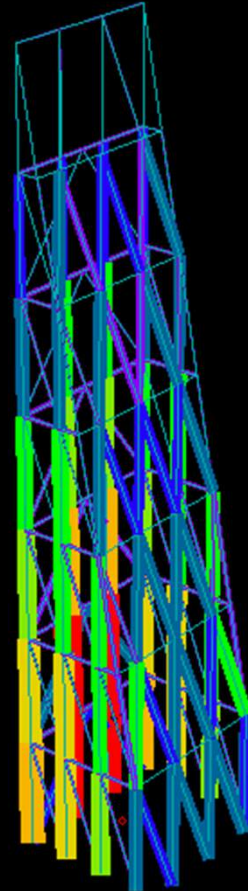
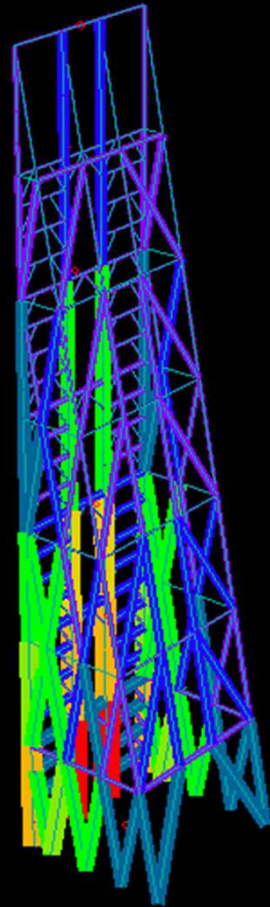
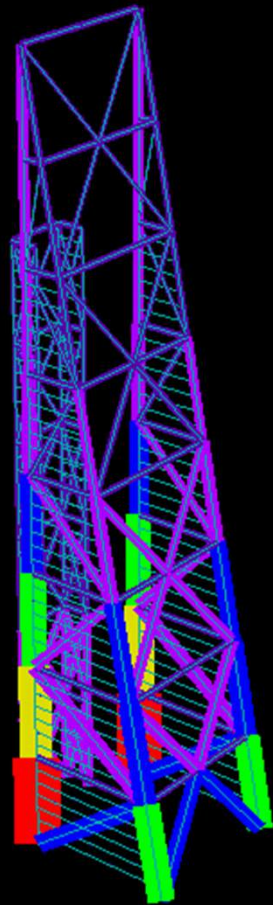
Efficiency and buildability

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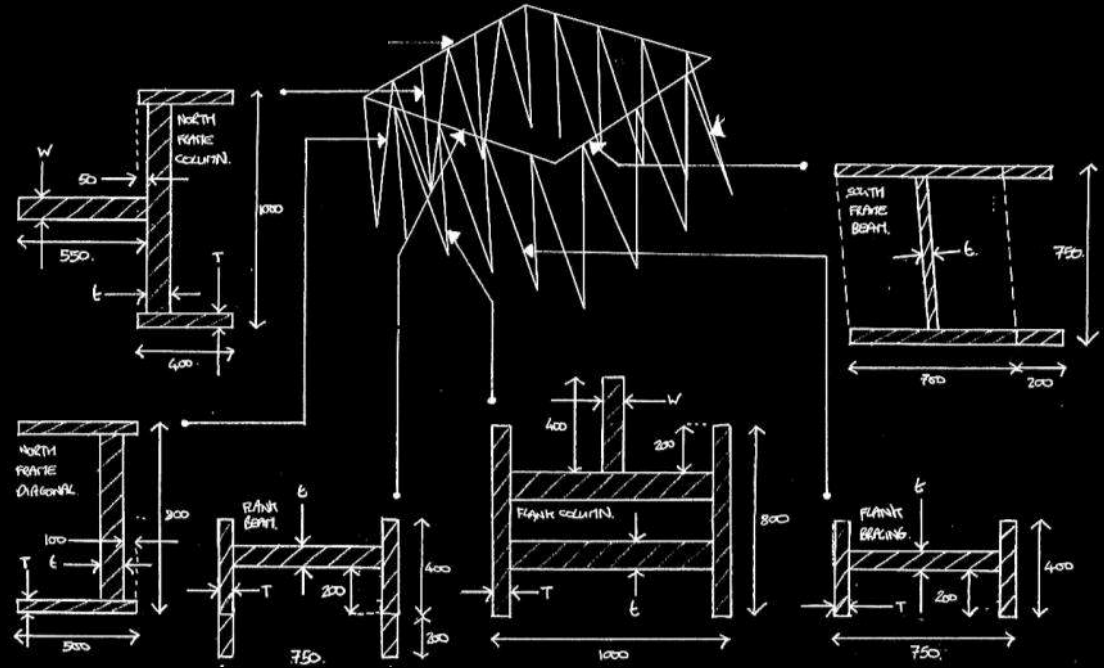
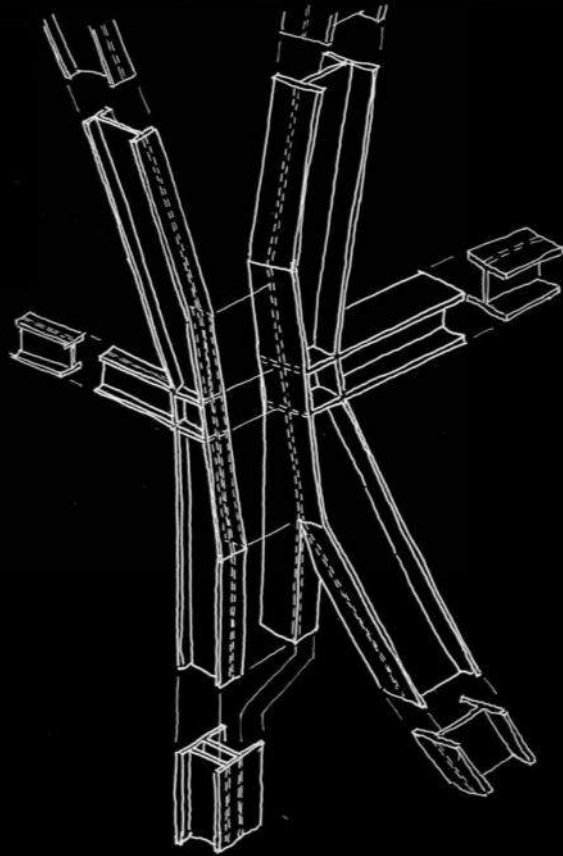
Efficiency and buildability

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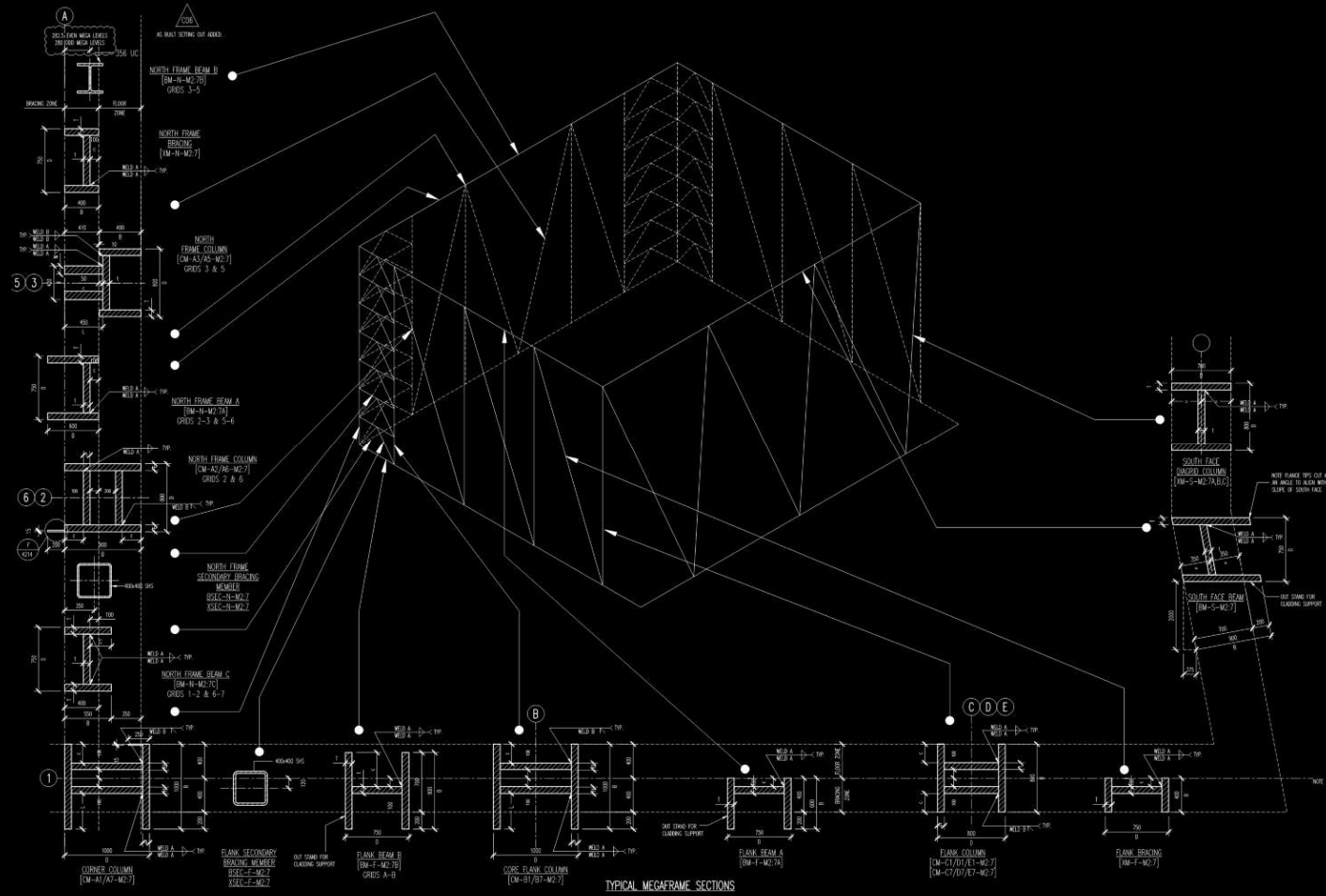
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122 LEADENHALL ST - ARUP JOB 68502
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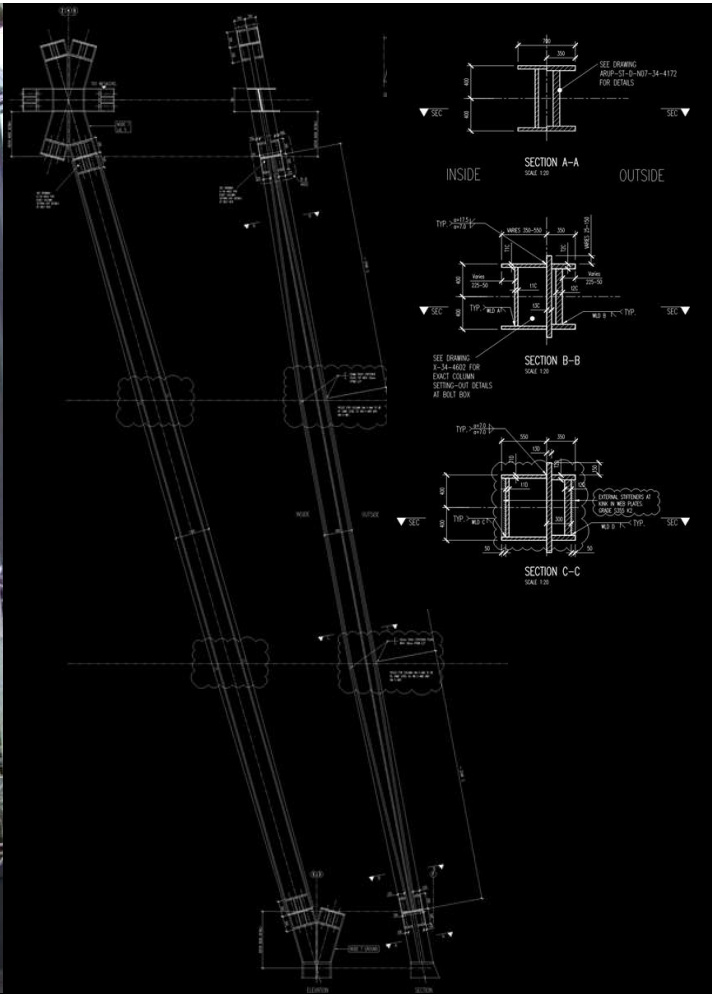
Efficiency and buildability

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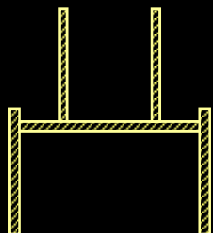
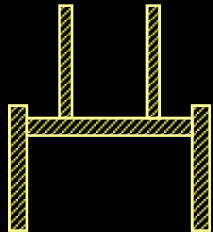
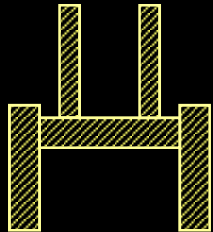
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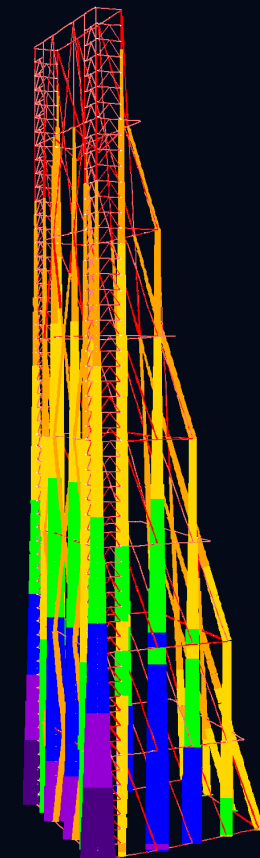
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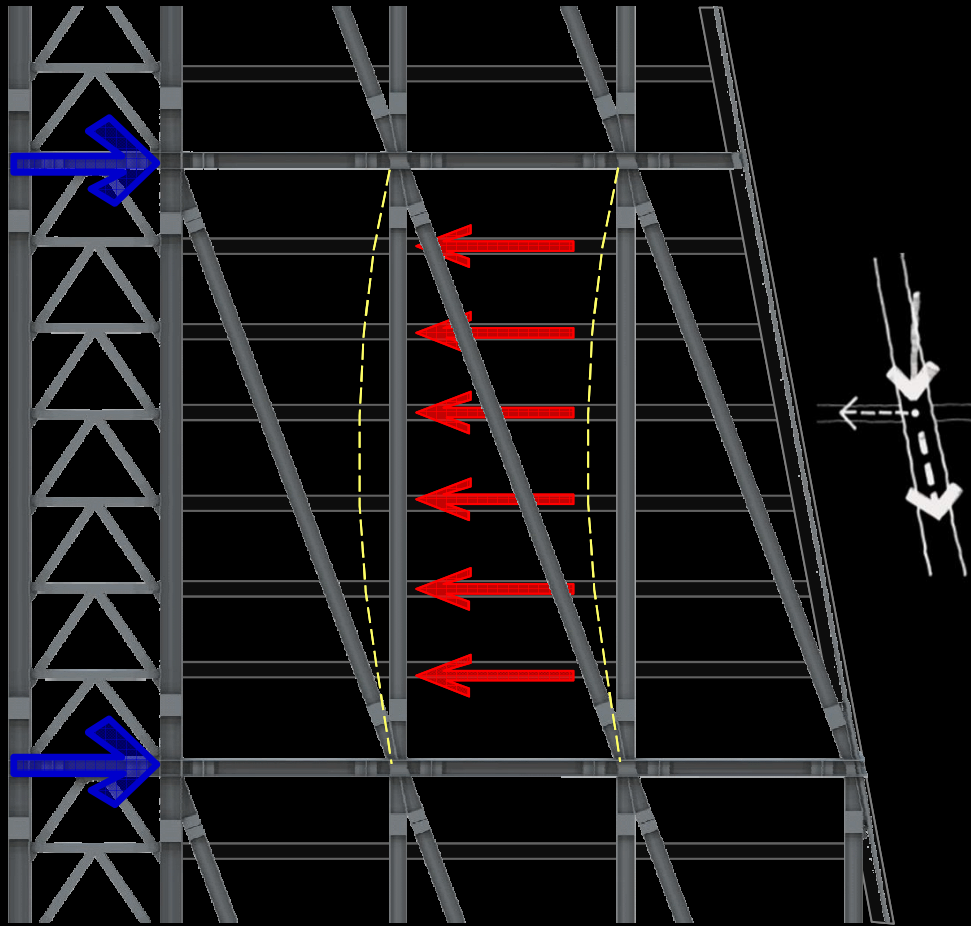
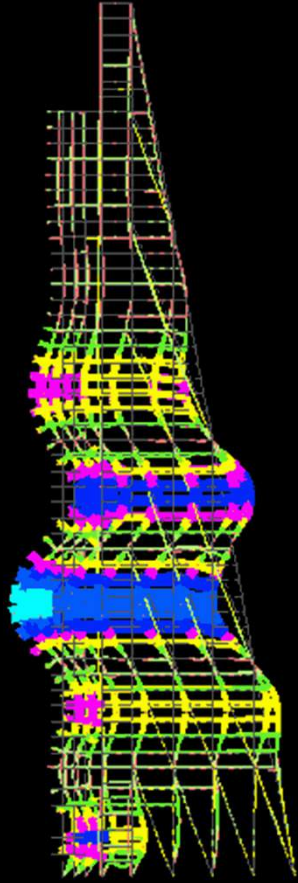
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			mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
227	333	North frame beam by secondary bracing 4C	750	1100	25	20				280	480		8,000	8,000
228	334	North frame beam by secondary bracing 5C	750	1100	25	20				280	480		8,000	8,000
229	335	North frame beam by secondary bracing 6C	750	1100	25	20				280	480		8,000	8,000
230	336	North frame beam by secondary bracing 7C	750	1100	25	20				280	480		8,000	8,000
231	337	North frame beam by secondary bracing 7C	750	1100	25	20				280	480		8,000	8,000
232	338	Vertical vertical	400	400	25	25					5		1,000	1,000
233	339	Vertical horizontal	400	400	25	25					5		6,000	6,000
234	340	Flank beam 1B	750	955	30	20				455			7,000	7,000
235	341	Flank beam 2B	750	955	30	20				455			7,000	7,000
236	342	Flank beam 3B	750	955	30	20				455			7,000	7,000
237	343	Flank beam 4B	750	955	30	20				455			7,000	7,000
238	344	Flank beam 5B	750	955	30	20				455			7,000	7,000
239	345	Flank beam 6B	750	955	30	20				455			7,000	7,000
240	346	Flank beam 7B	750	955	30	20				455			7,000	7,000
241	347	Flank beam 8B	750	955	30	20				455			7,000	7,000
242	350	Basement column 16											3,000	3,000
243	351	Basement column 16	800	900	50	50				250			6,000	6,000

1. Section size		5. Section properties (effective)	
Type:	Double-I	Area:	84,372 mm ²
Eff length (X):	12,000 mm	I _x :	6.91E+09 mm ⁴
Eff length (Y):	12,000 mm	I _y :	3.50E+09 mm ⁴
D:	600 mm	Z _x :	1.73E+07 mm ³
B:	500 mm	Z _y :	8.27E+06 mm ³
T:	35 mm	r _x :	286.1 mm
t:	30 mm	r _y :	203.5 mm
c:	50 mm	S _x :	1.75E+07 mm ²
L:	450 mm	S _y :	mm ²
w:	35 mm	A _e :	mm ²
d:	400 mm	J:	3.21E+07 mm ⁴
2. Local section checks		6. Buckling capacity	
max thickness:	35	Por:	97.0 MN
pg:	345	λ _{cr} :	18.0
z:	0.89	a:	5.5 curve (c)
Outstand:	12.00	Lambda:	41.9
Flange:		Lambda ₀ :	15.8
Web:	24.33	pE:	150.0
Sub:	12.86	η:	0.14
Class:	Slender	φ:	820.2
Design:	Elastic	pe:	273.4
3. Elastic centroid		7. Bending capacity	
Part	Area	x	y
Flange:	34,036	243.1	400.0
Web:	21,900	65.0	400.0
Sub:	28,436	-153.1	400.0
		Area _x	Area _y
		8,274,566	13,614,341
		1,423,500	8,760,000
		-4,353,905	11,374,341
		G _s :	78.8
		β ₁ :	0.90
		β ₂ :	397.1
		h:	2,47E+14 mm ⁶
		β _w :	10
		ε _{lt} :	7.0
		η _{lt} :	0.34
		φ _{lt} :	622.8
		pb:	228.0 N/mm ²
		Mcr/M _t :	11.5



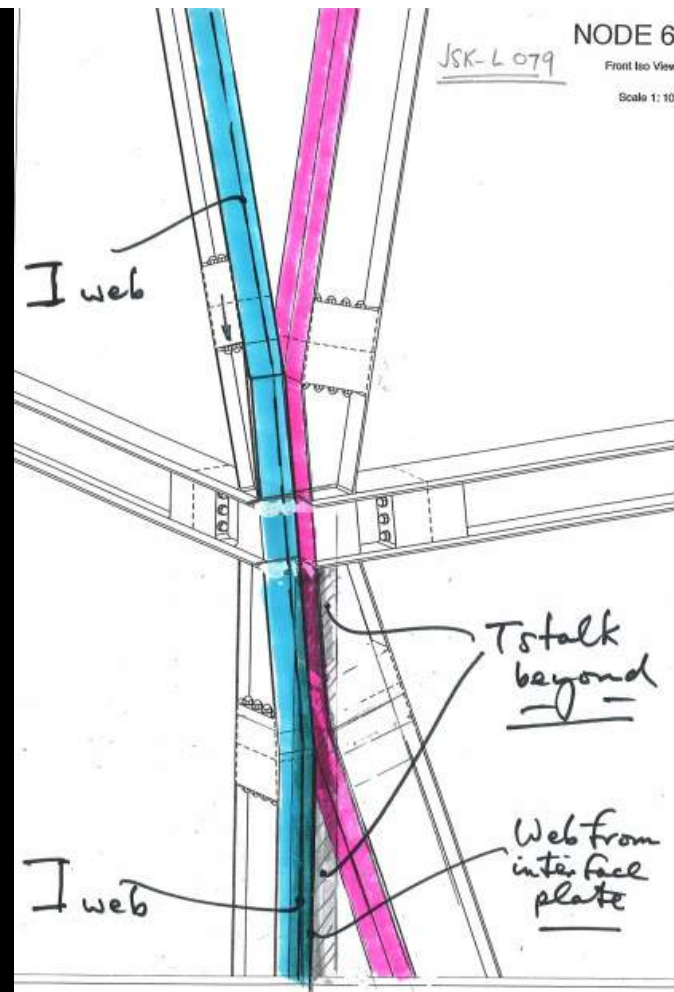
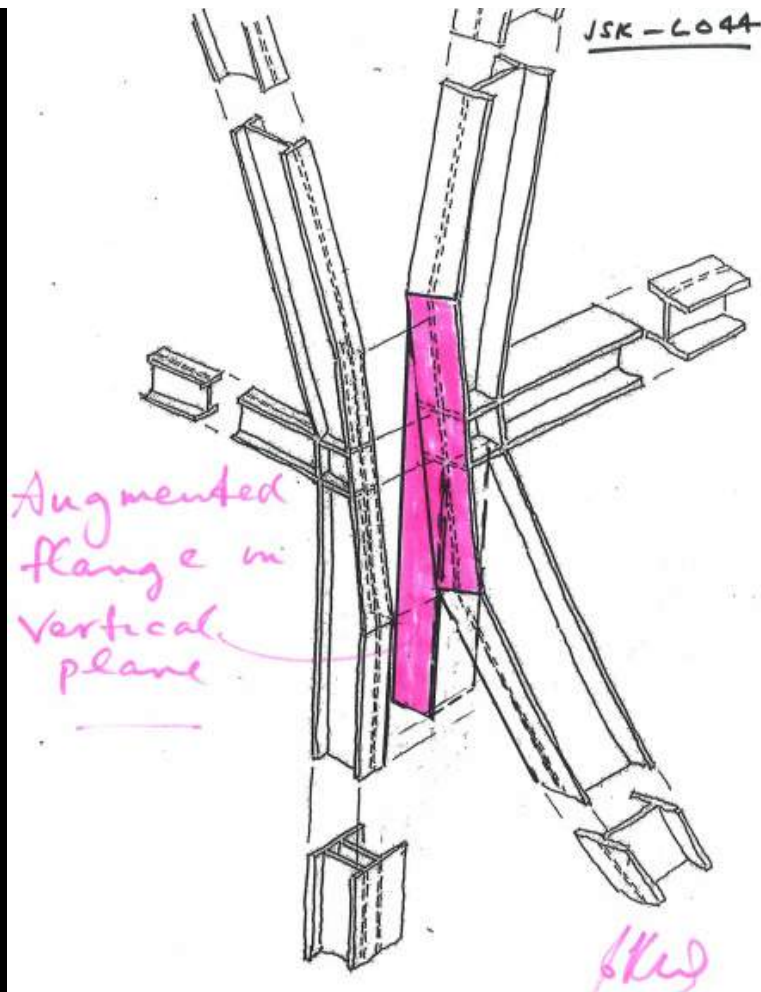
Efficiency and buildability

ARUP



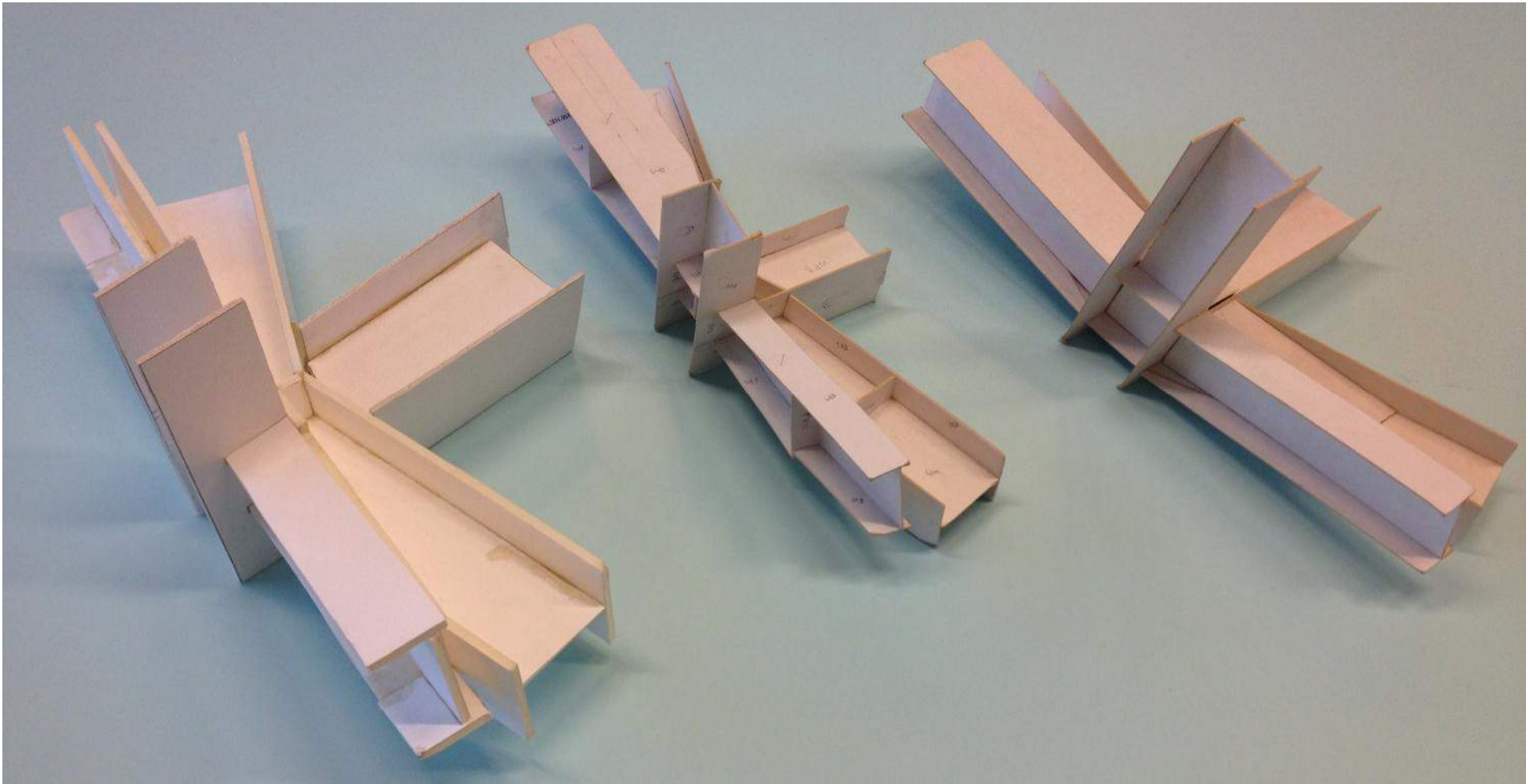
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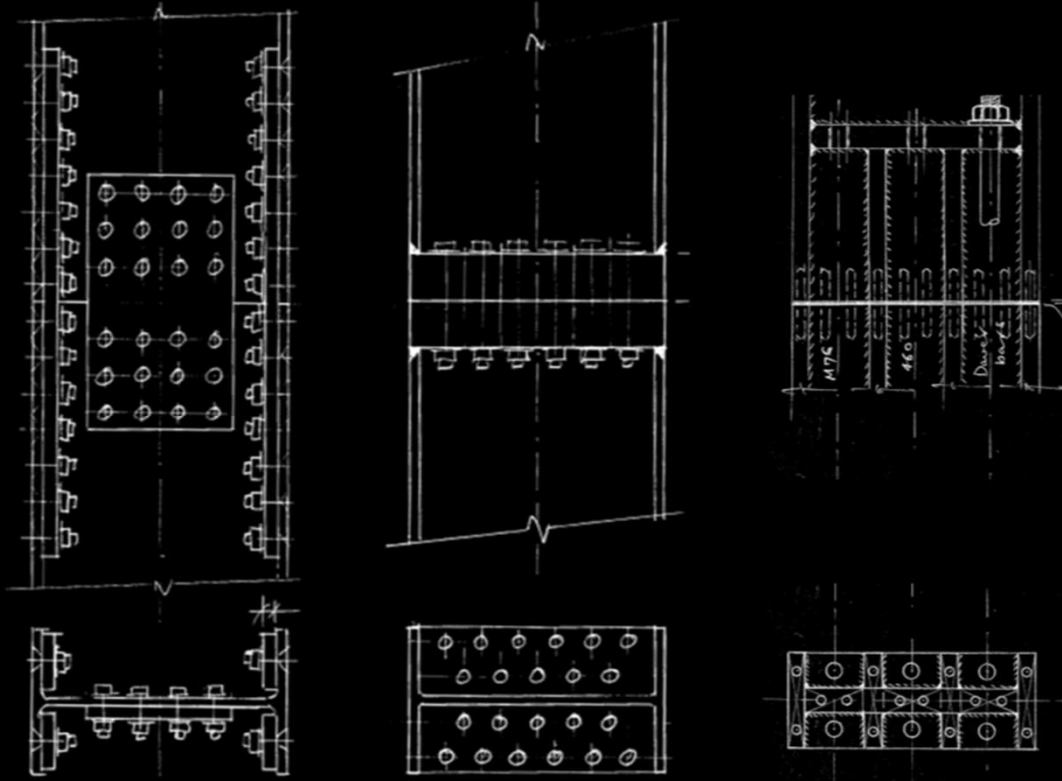
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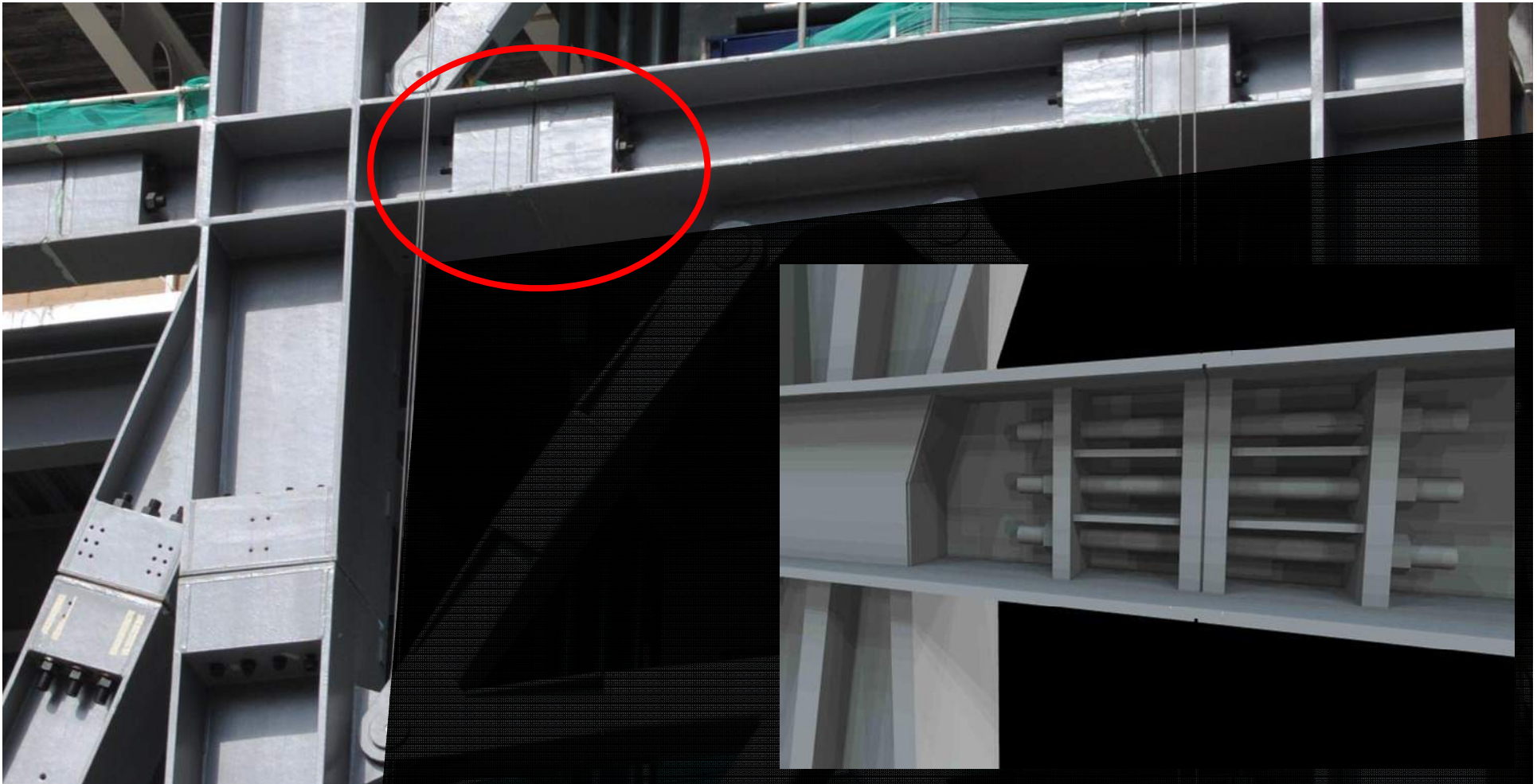
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Efficiency and buildability

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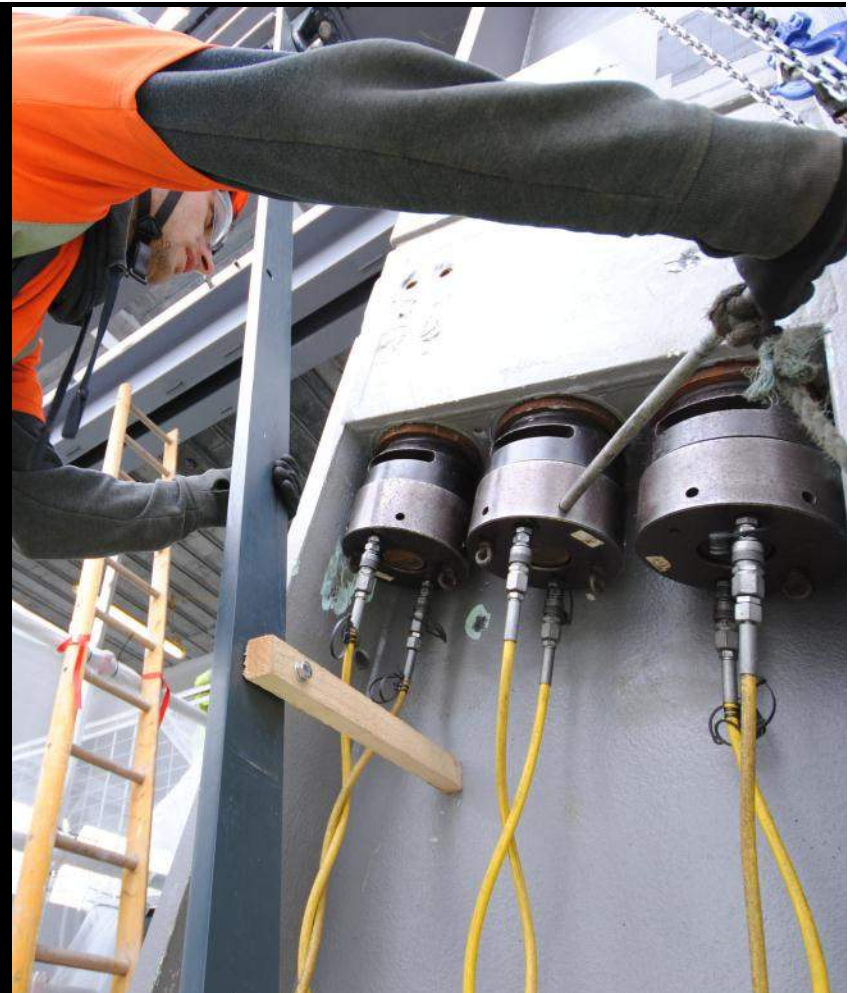


Efficiency and buildability

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Efficiency and buildability



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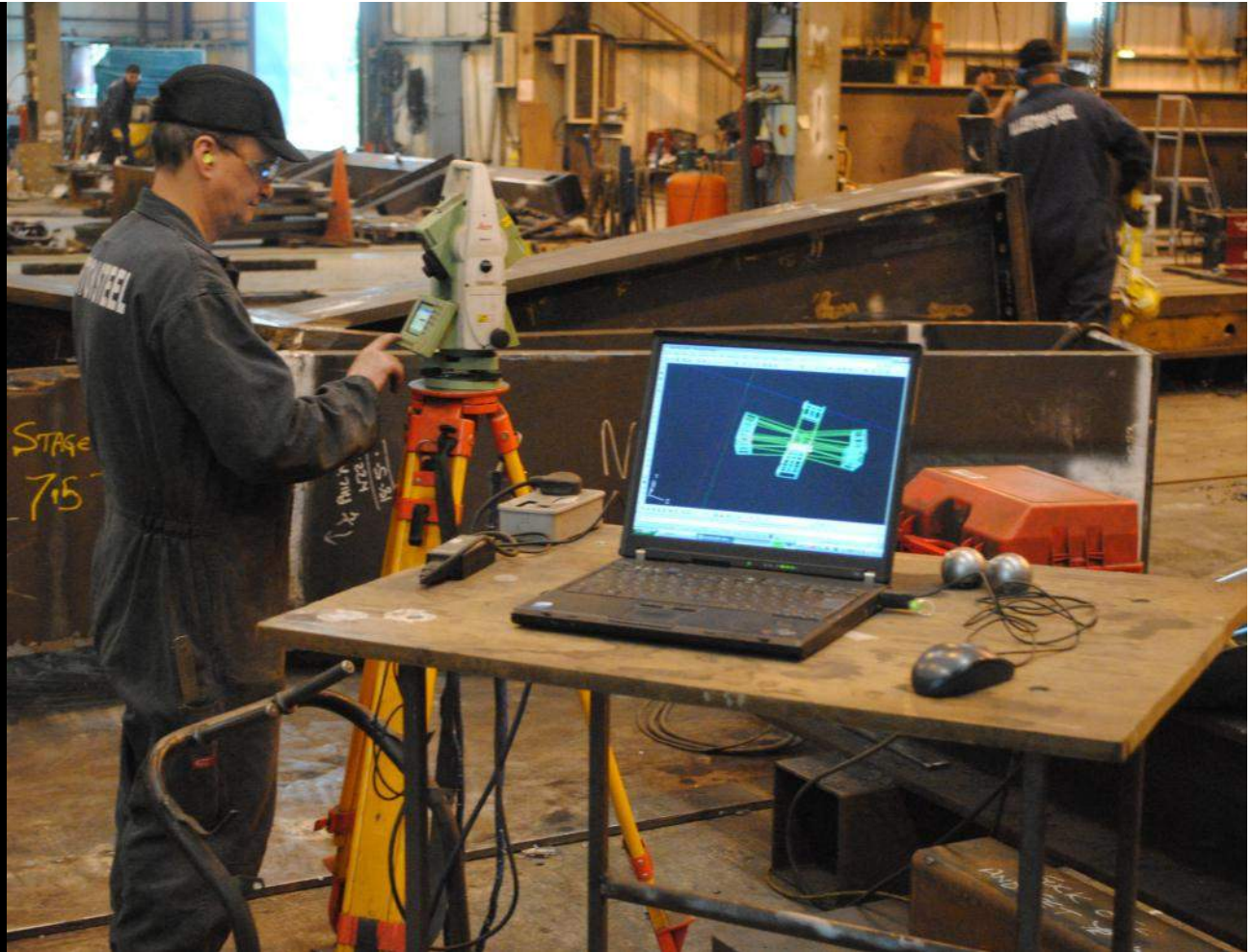
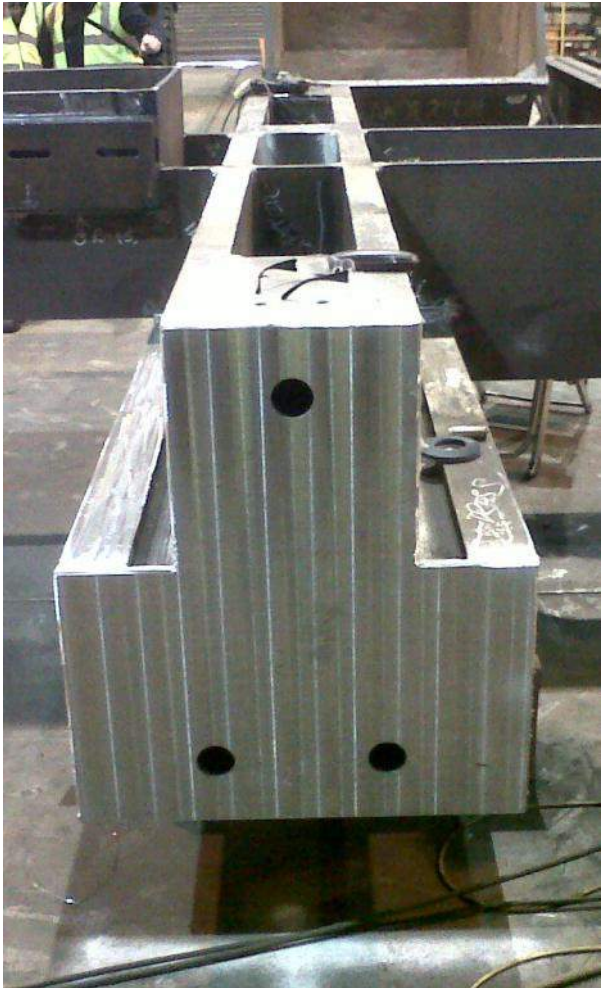
Efficiency and buildability

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Efficiency and buildability

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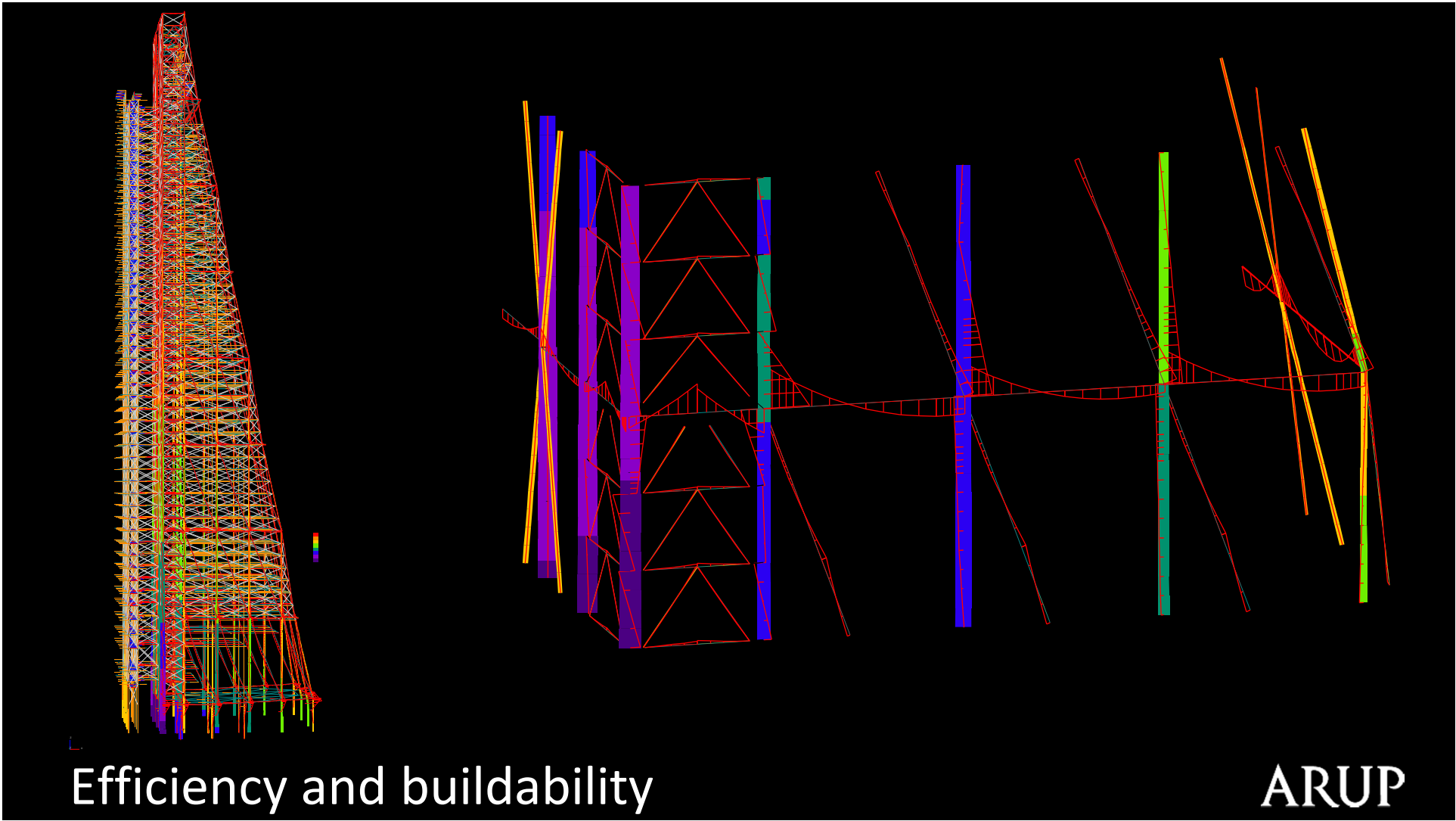
Efficiency and buildability

ARUP



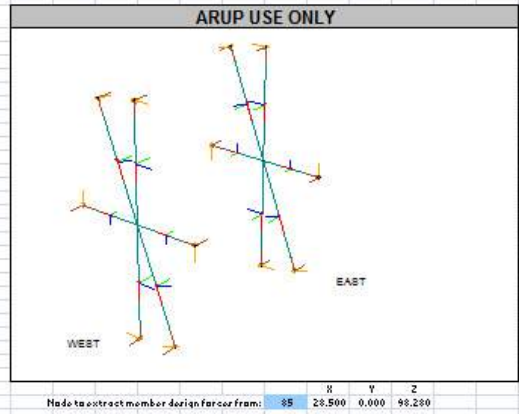
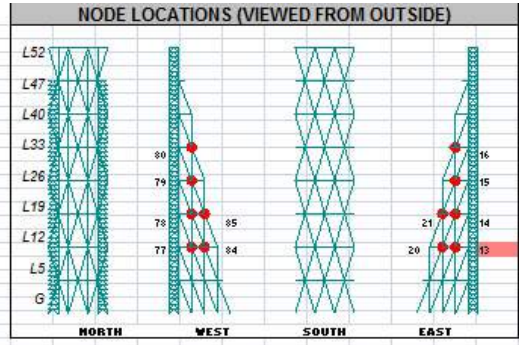
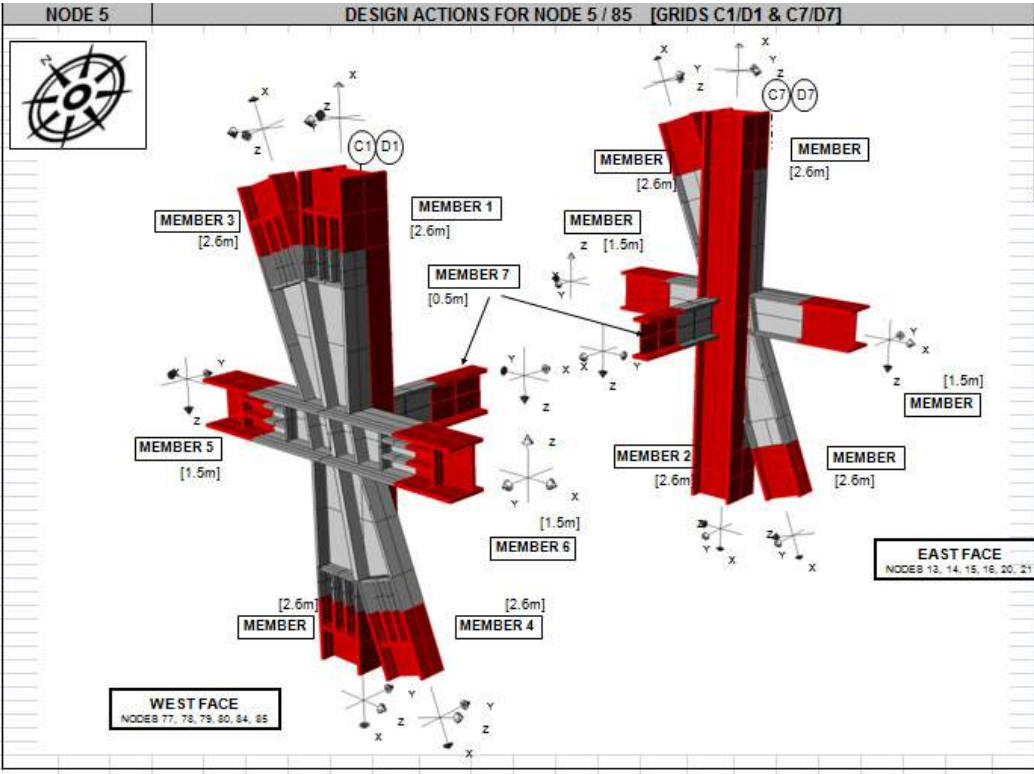
Efficiency and buildability

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Efficiency and buildability

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1. Refertaintducts
2. See schedule 0310
to be designed during and
these members are fo

ARUP

THE LEADENHALL BUILDING
60502
16/05/2008

Level 5 Meqframe H
ARUP-ST-RP-0007r

Page 7AL API

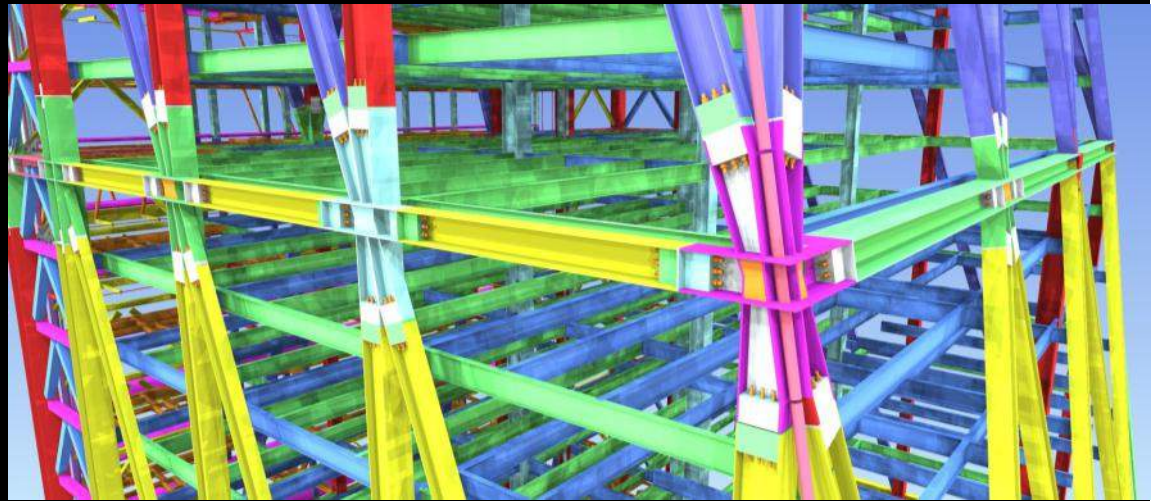
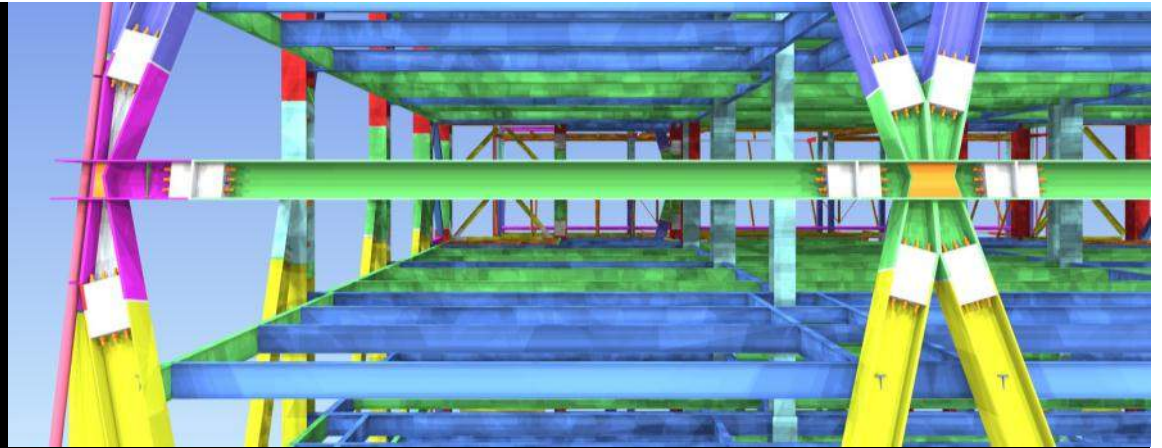
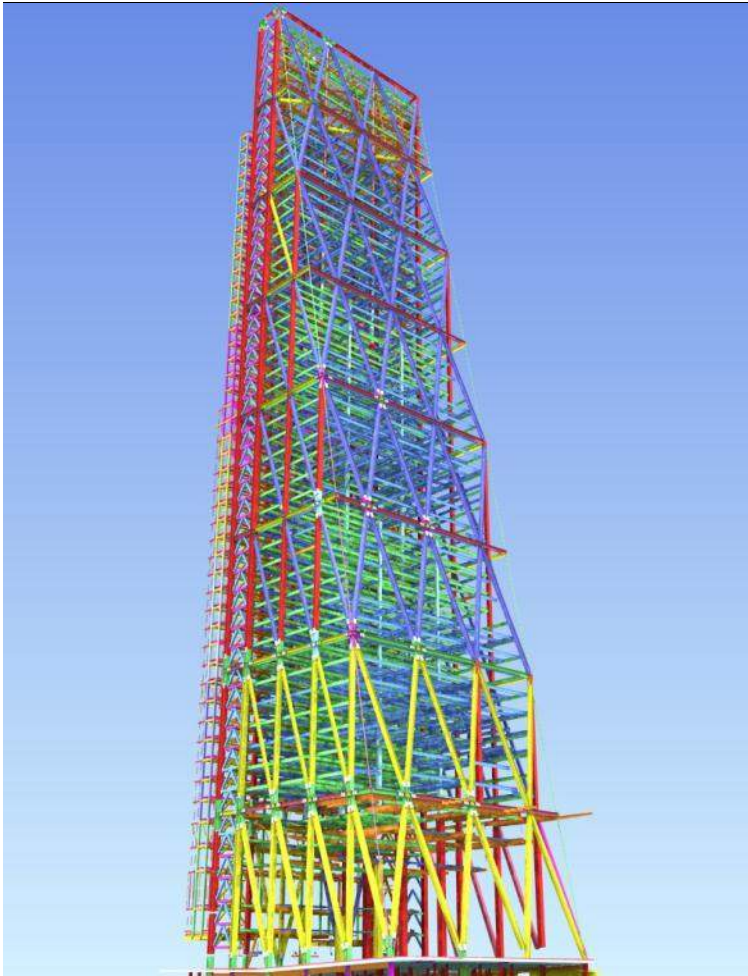
GSA model 075

MEMBER SERVICE DESIGN FORCES FROM GSA

Load case	Type	MEMBER 1						MEMBER 2						MEMBER 3						MEMBER 4						MEMBER 5						MEMBER 6						MEMBER 7															
		Fx	Fy	Fz	Mx	My	Mz	Fx	Fy	Fz	Mx	My	Mz	Fx	Fy	Fz	Mx	My	Mz	Fx	Fy	Fz	Mx	My	Mz	Fx	Fy	Fz	Mx	My	Mz	Fx	Fy	Fz	Mx	My	Mz	Fx	Fy	Fz	Mx	My	Mz										
Dead+SuperDead	D+SDL	-6,528	223	22	34	10	1	-7,245	-269	-48	30	24	1	264	139	1	32	0	0	310	-126	-1	24	-1	0	4	254	-2	-5	0	-38	-1	-547	2	-175	3	11	-11	-28	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Active Alignment	AA	2,426	-169	3	-21	-3	1	2,311	245	-5	-29	-4	2	2,074	-119	1	-44	0	0	2,078	132	-1	-43	0	0	-12	-593	0	152	-1	0	-7	151	0	40	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Live	LL	-2,673	65	4	10	31	0	-2,829	-74	-26	8	50	0	118	39	-3	8	1	0	114	-34	3	7	0	0	-3	159	-1	-41	0	0	1	-57	-2	-15	2	0	-17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nat X	NHL	145	-55	1	-10	-1	0	108	44	-1	1	-1	0	-870	-28	0	-6	0	0	-847	14	0	-1	0	0	28	-98	-1	26	0	0	0	34	1	9	-1	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nat Y	NHL	-145	55	-1	10	1	0	-108	-44	1	-1	1	0	870	28	0	6	0	0	847	-14	0	1	0	0	-28	98	1	-26	0	0	0	-34	-1	-9	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nat Z	NHL	628	-10	10	-2	-1	0	799	3	13	0	10	0	124	-9	1	-3	0	0	-95	1	2	-1	1	0	-61	-5	-4	3	0	0	-2	21	-4	5	5	0	-12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

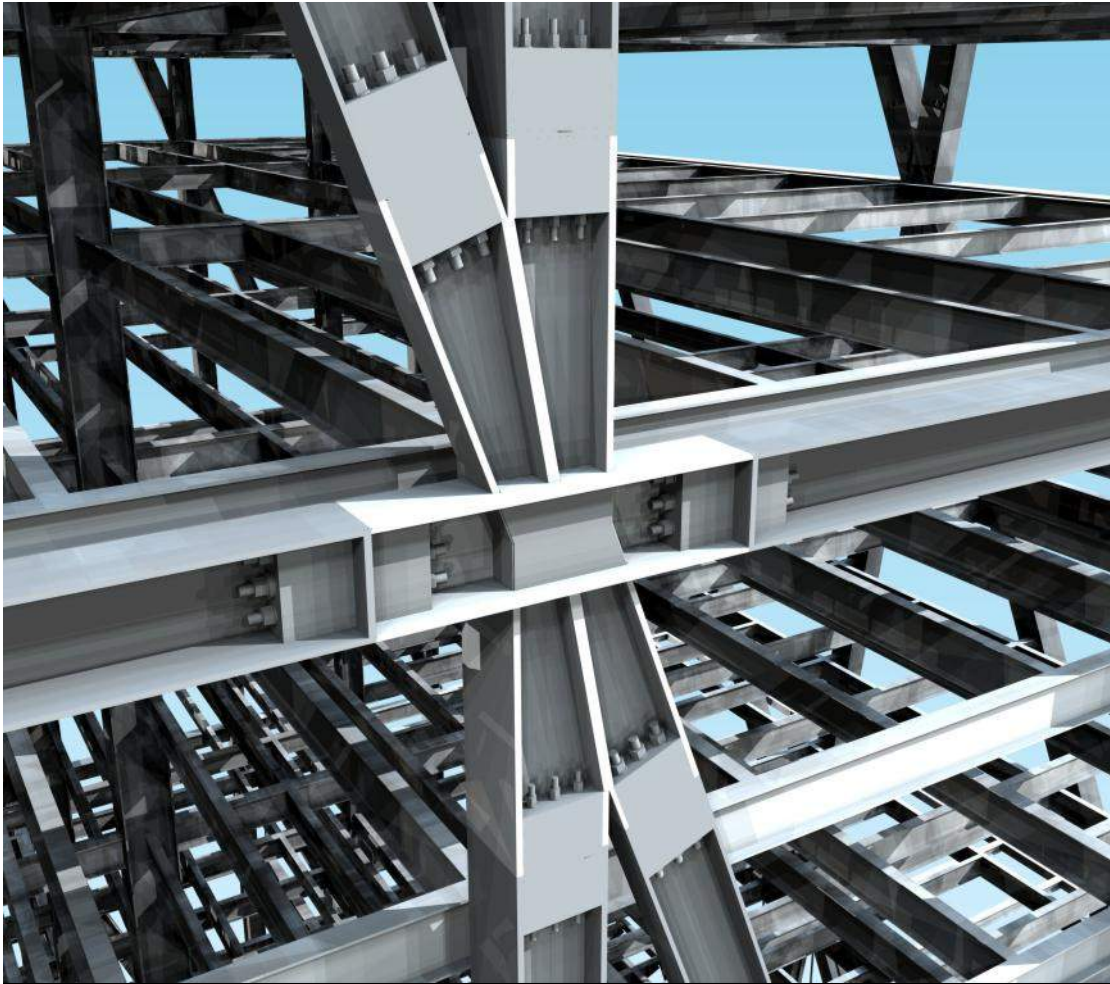
Efficiency and buildability

ARUP

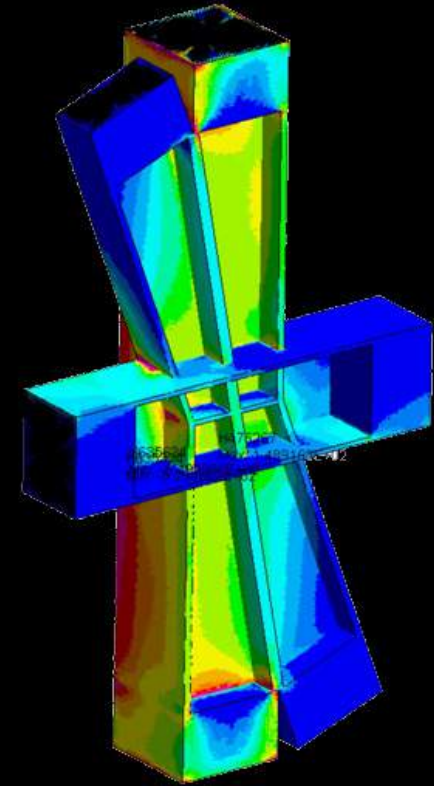


Efficiency and buildability

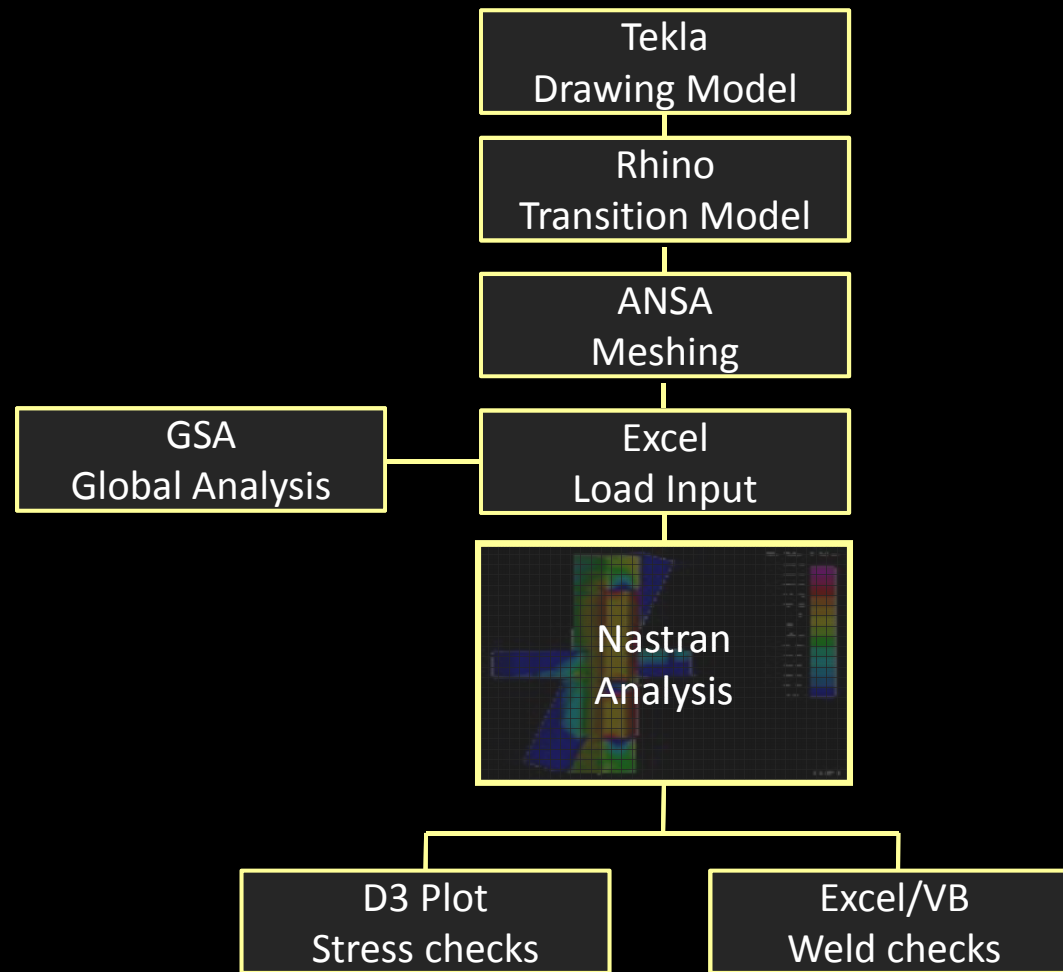
ARUP



Efficiency and buildability

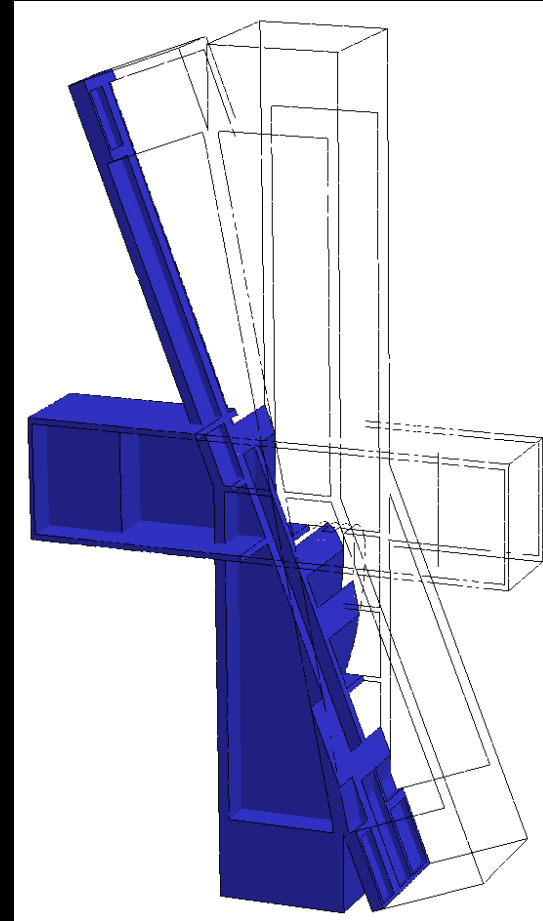
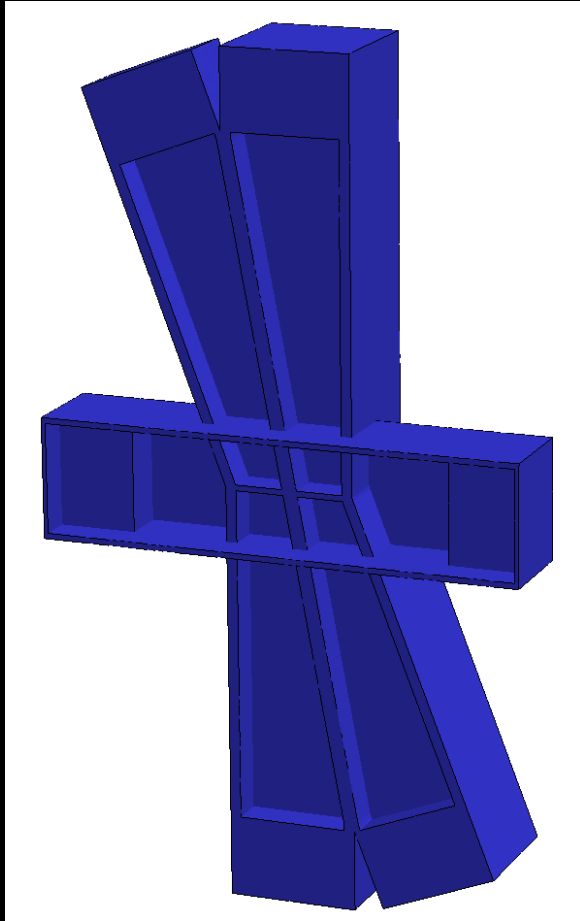


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Efficiency and buildability

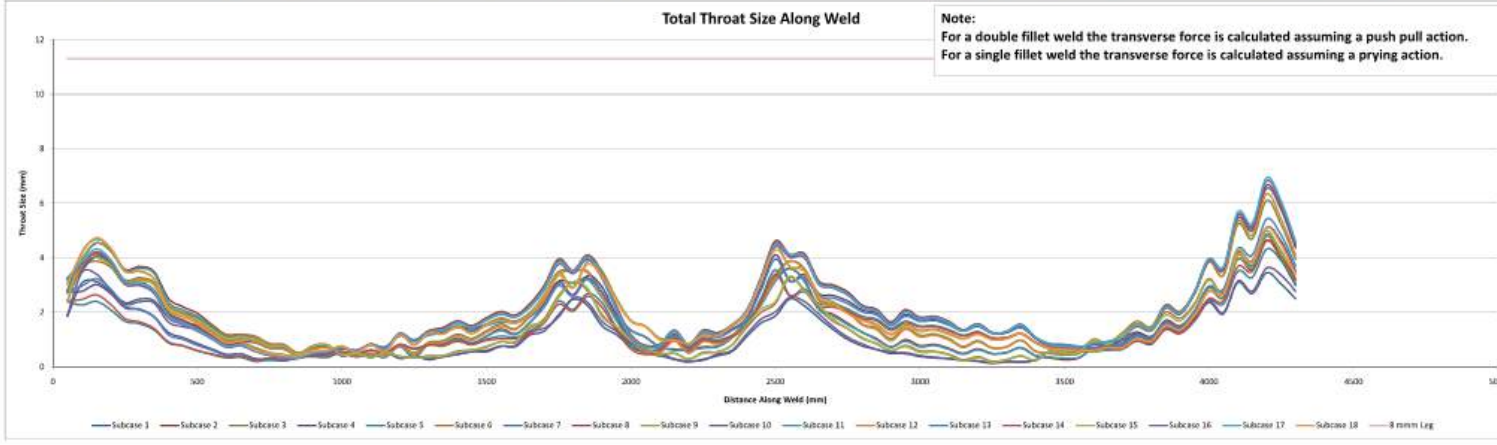
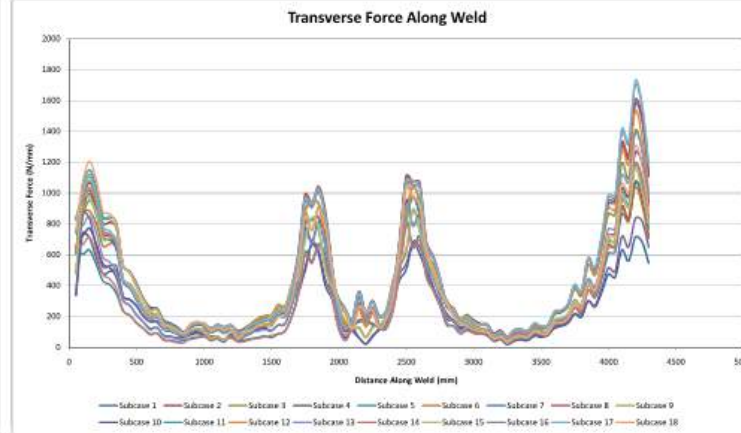
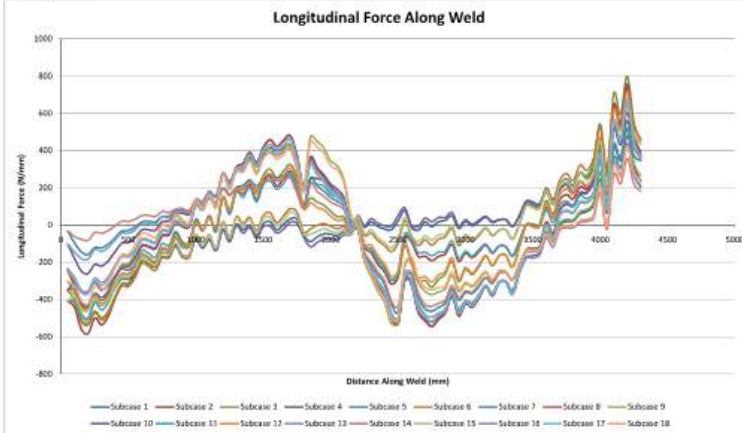
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Efficiency and buildability

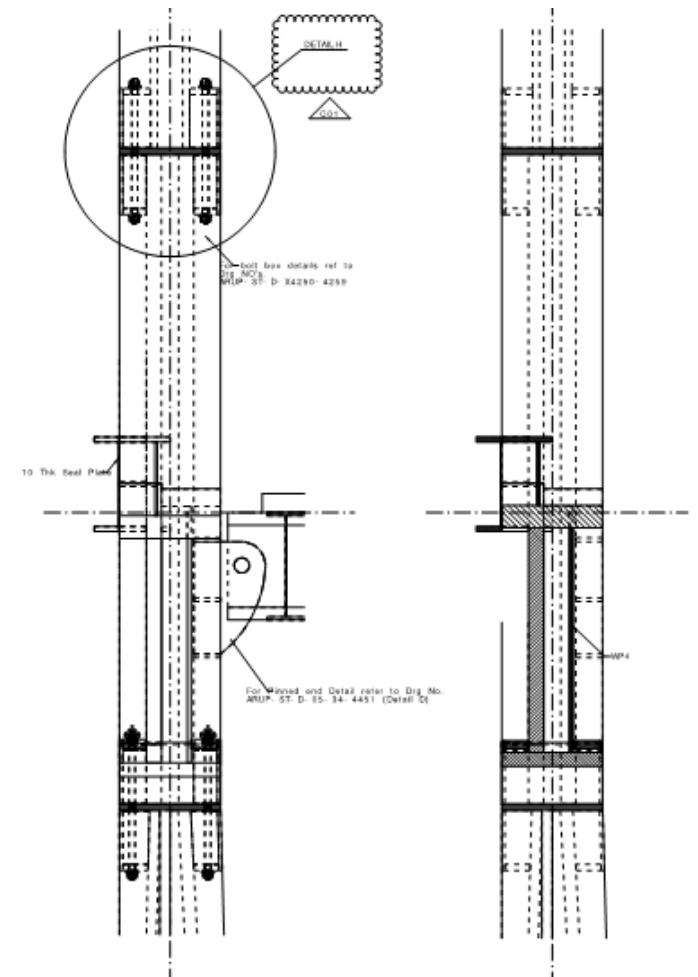
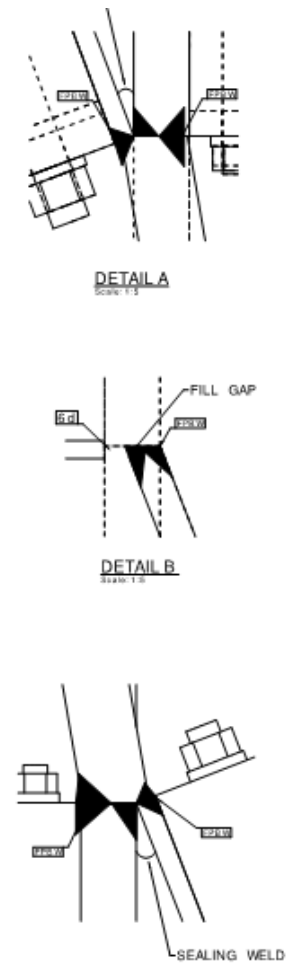
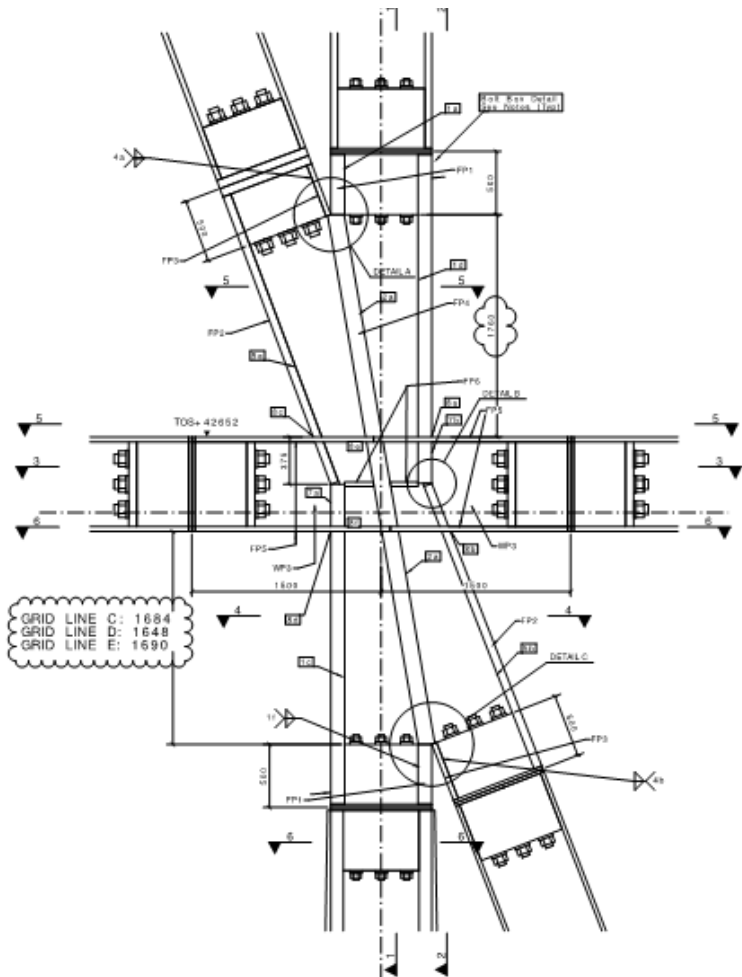
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OW_DS

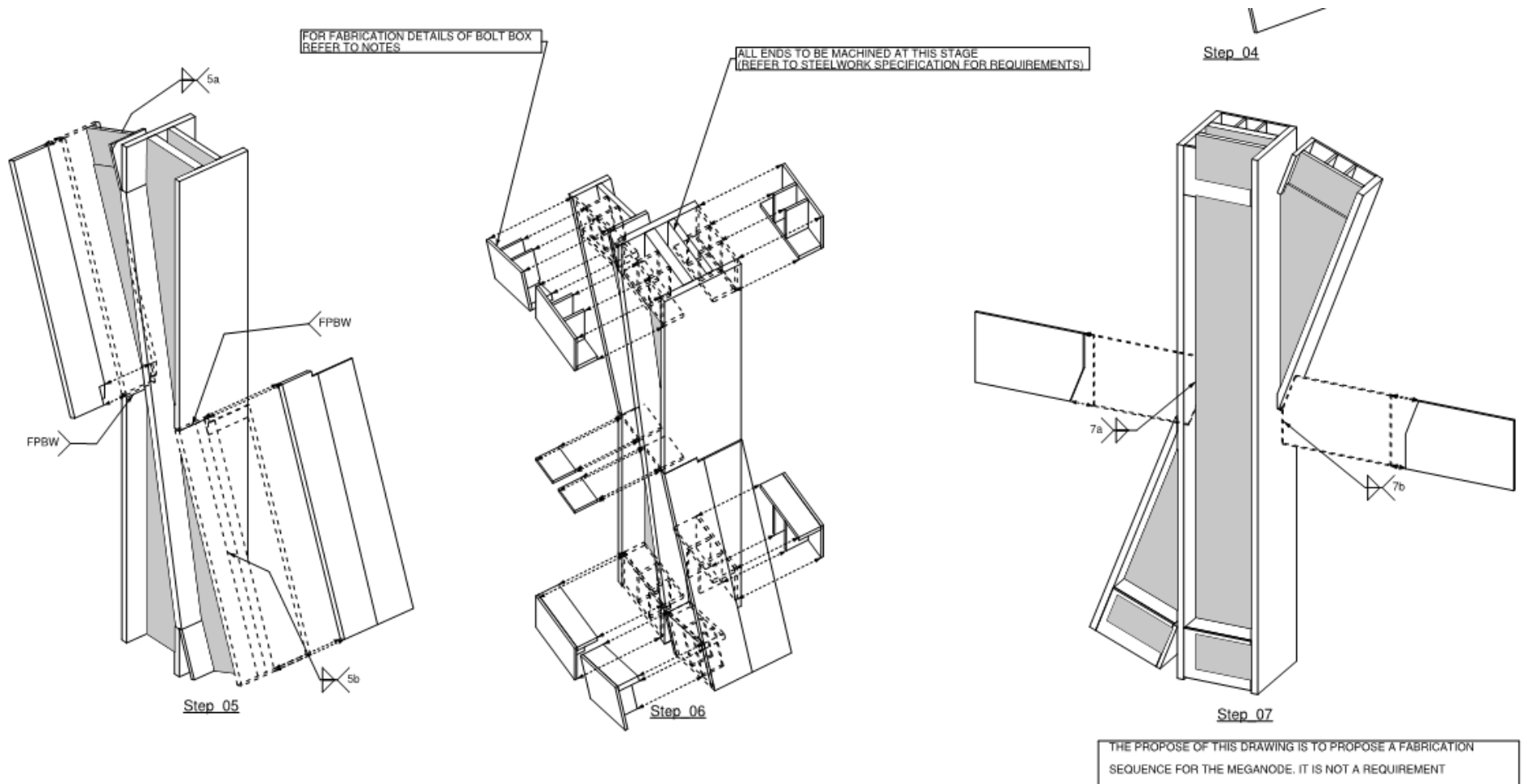


Efficiency and buildability

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Efficiency and buildability ARUP



Efficiency and buildability

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Efficiency and buildability

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Engineering systems

The challenge of the megaframe

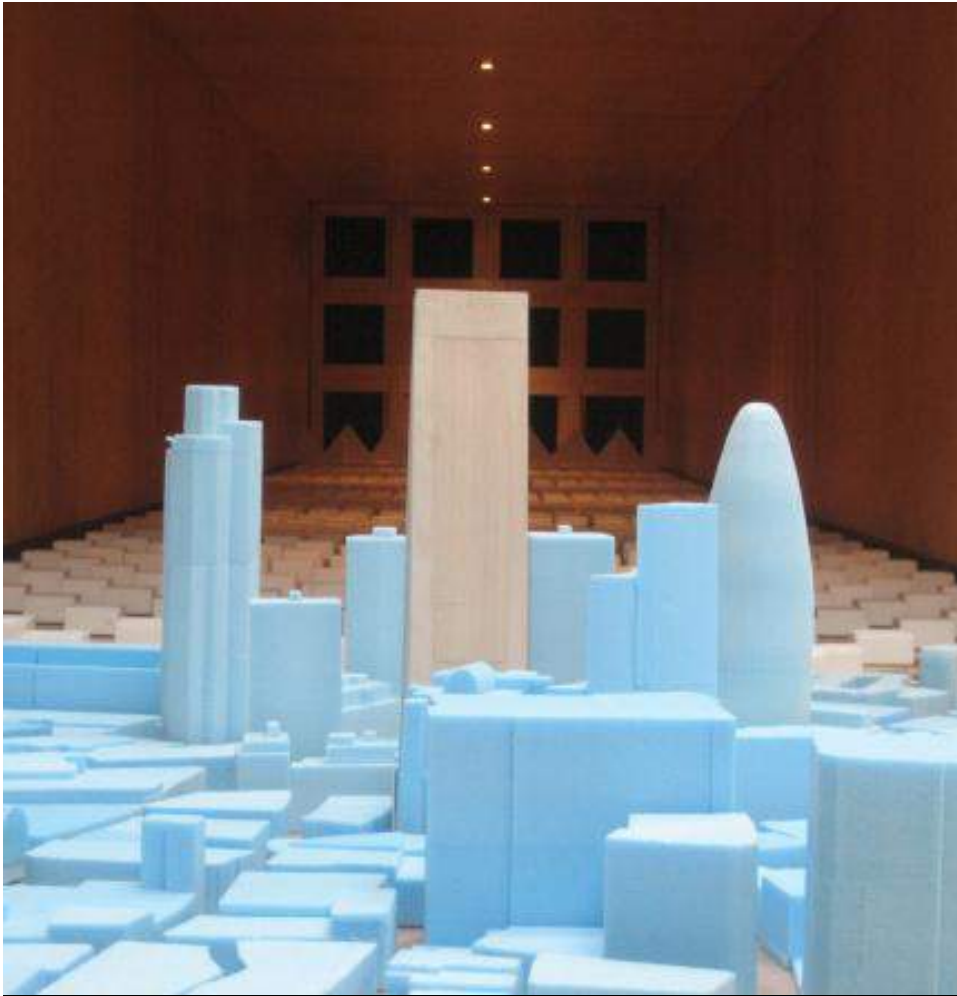
Efficiency and buildability

Managing movements

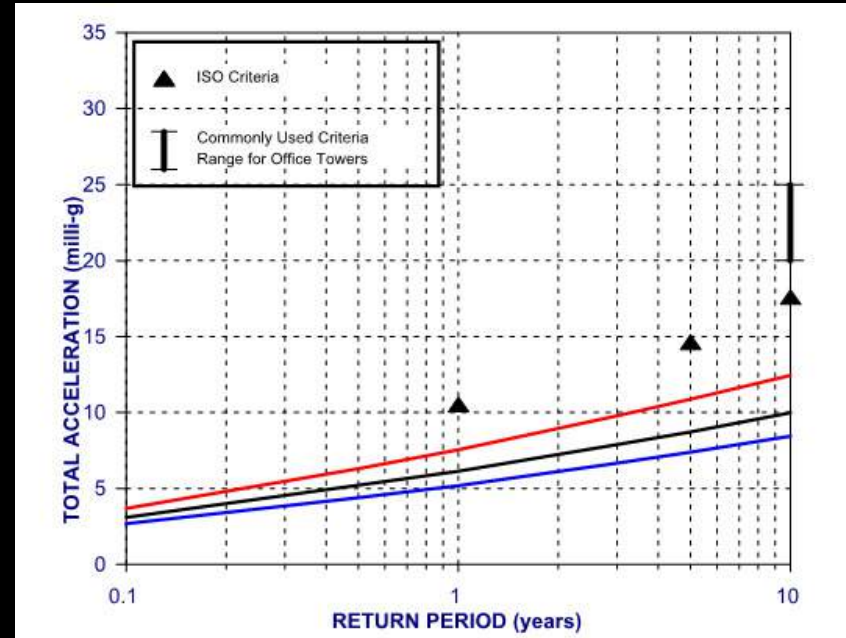
Lessons learned

The Leadenhall Building

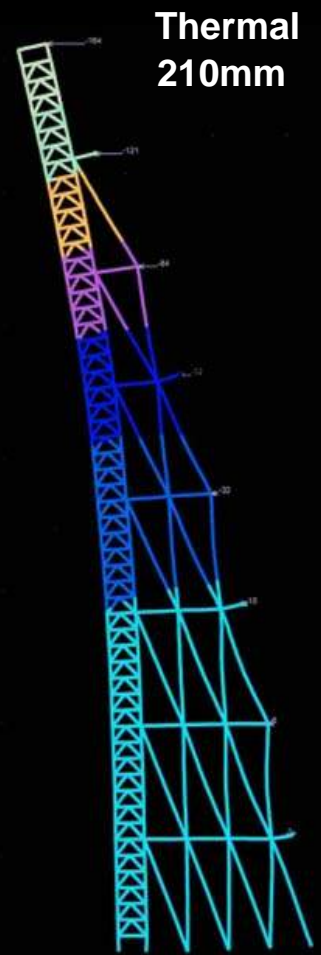
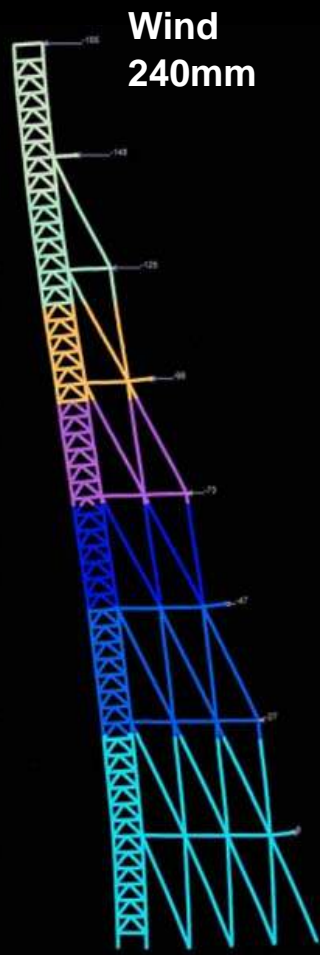
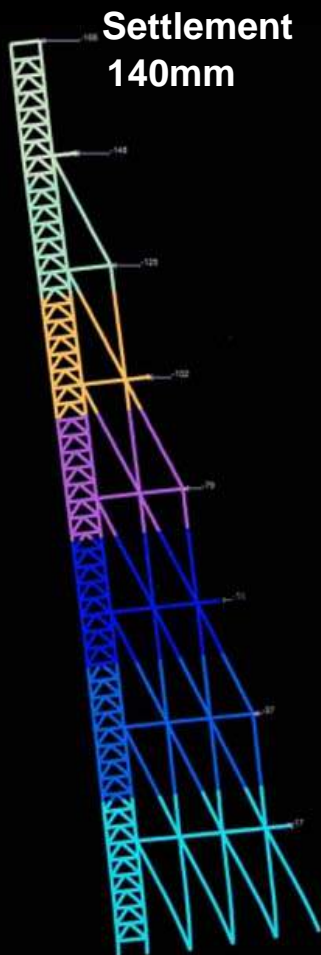
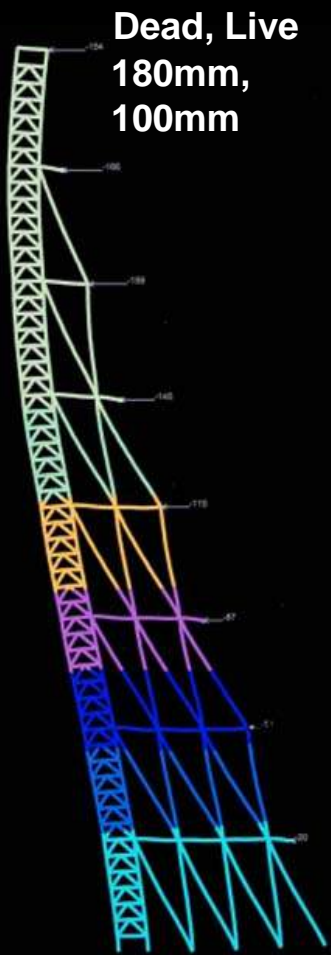
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Managing movements

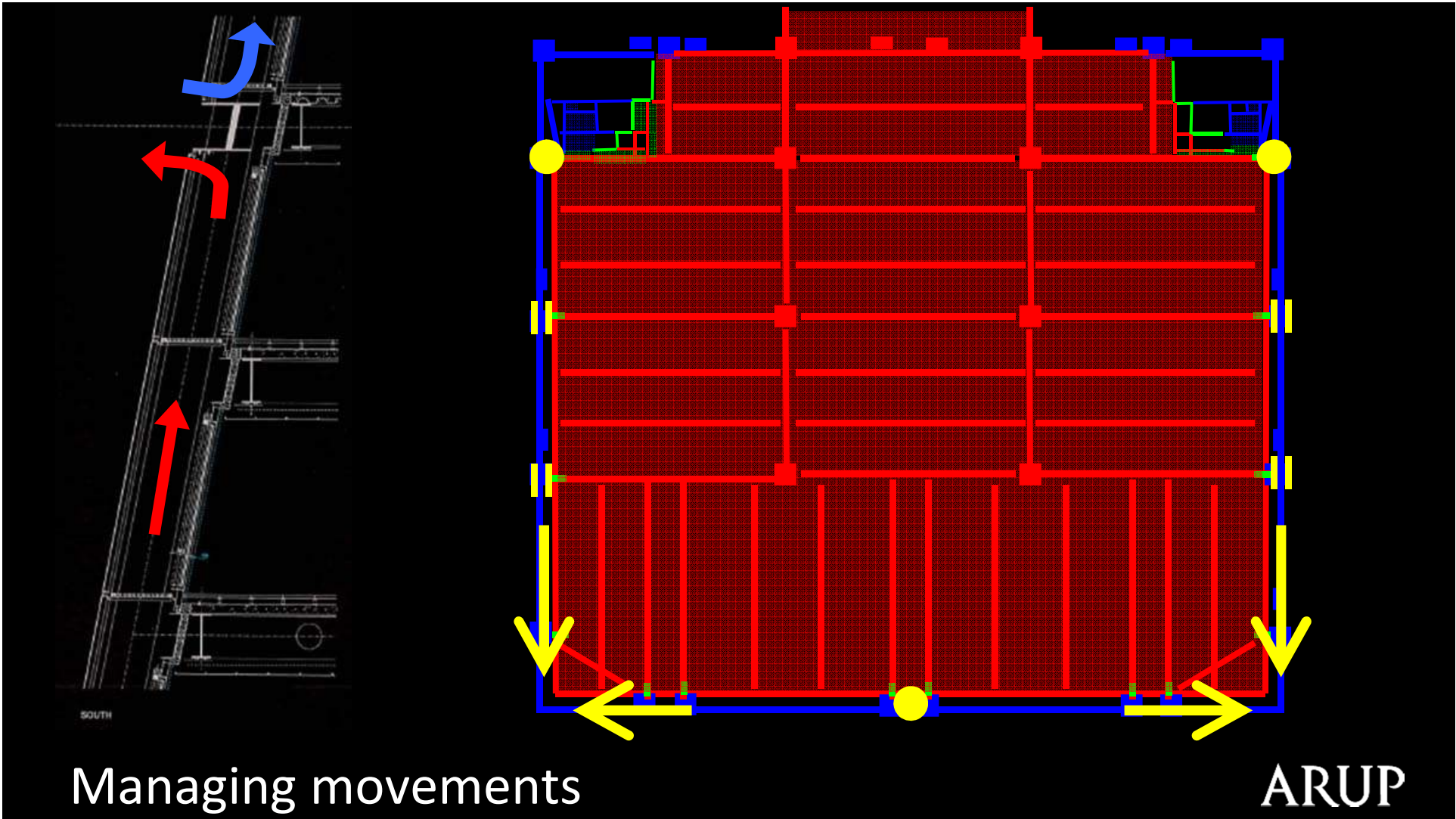


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Managing movements

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Managing movements

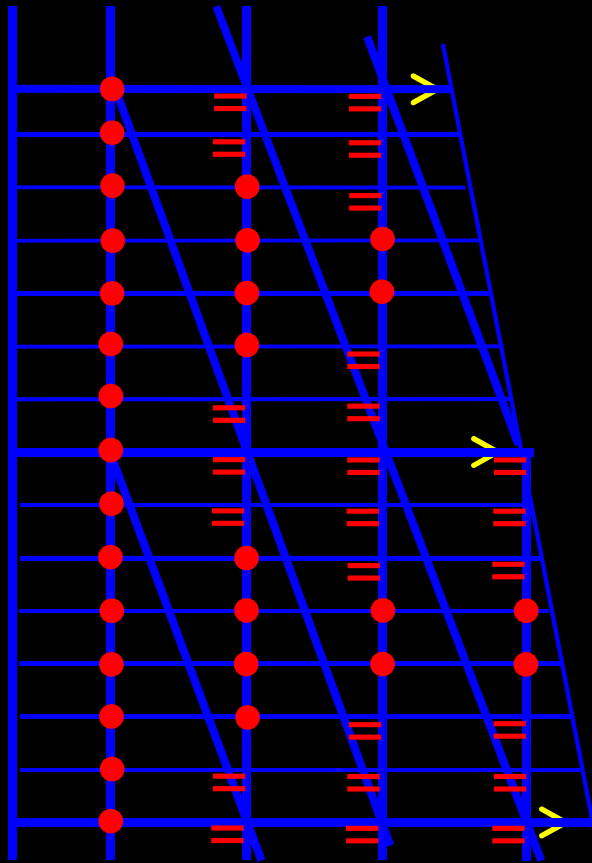
ARUP



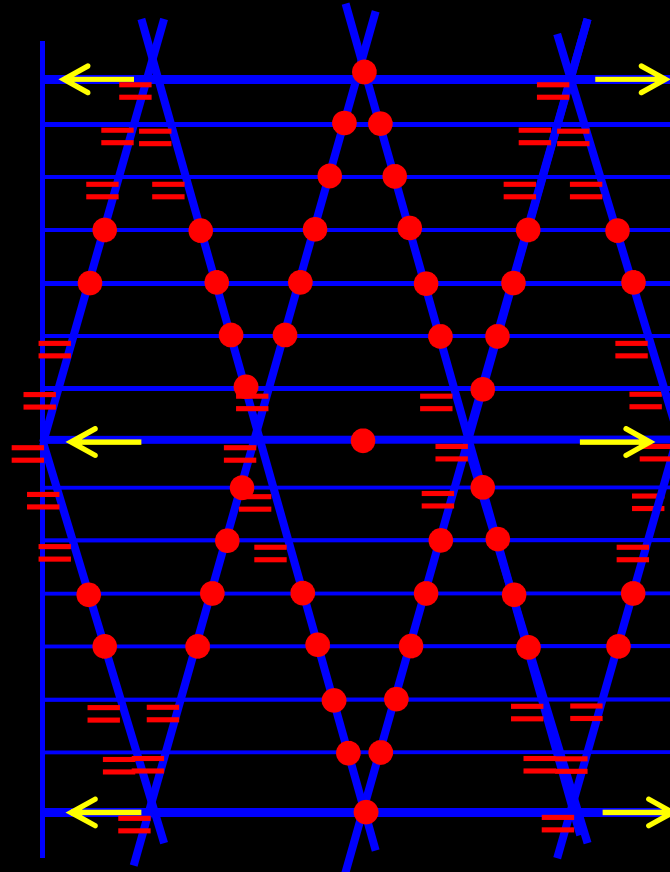
Managing movements



ARUP



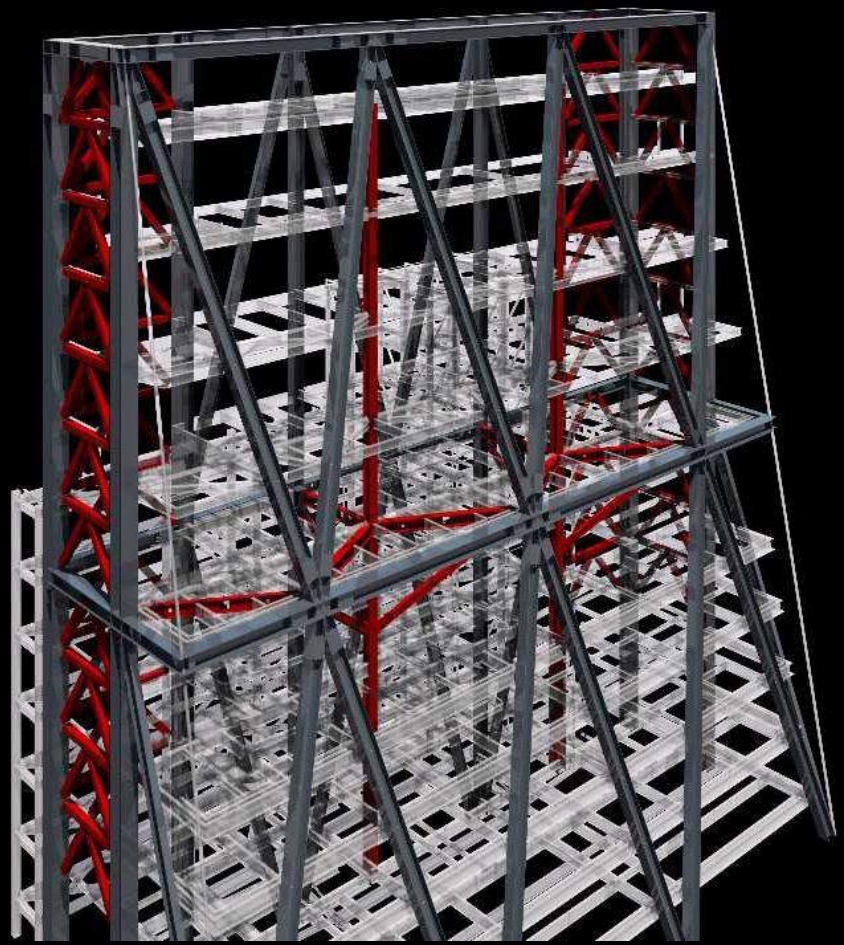
Managing movements



- Pinned
- = Sliding

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ALL TILTS IN FLOOR
TO TEMPERATURE
ARE LESS THAN OR
TO 3 MM EXCEPT
INDICATED.



Managing movements

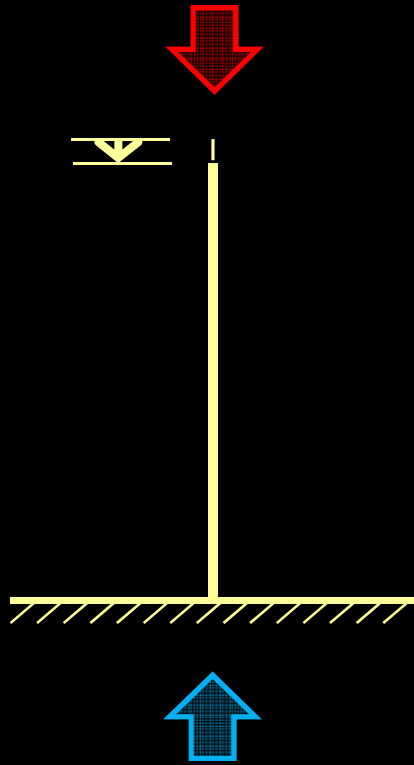
ARUP



Managing movements

ARUP

Axial shortening



Managing movements

ARUP

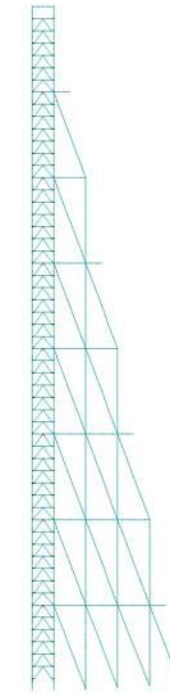
Leadenhall Street
Stability model

ARUP



Job No.	Sheet No.	Rev.
68502		
Dwg. Ref.		
Made by cm	Date 25-Nov-2011	Checked

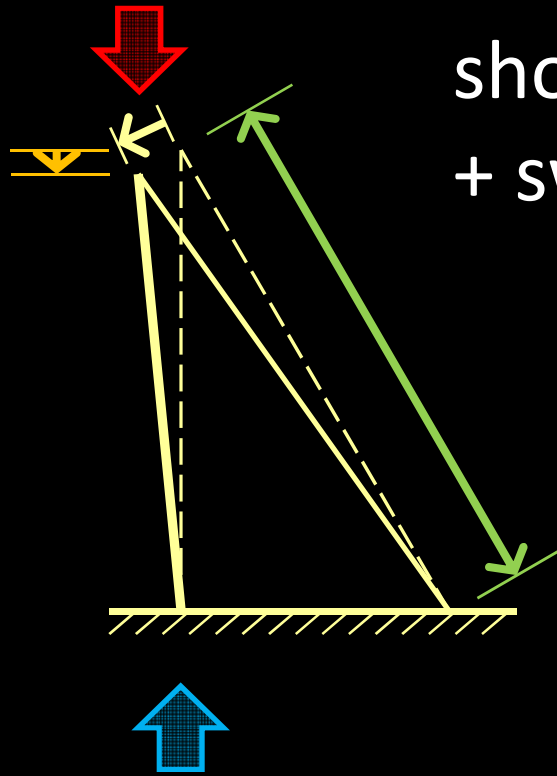
Dead load
movement



Element list: "Mega Level 8"
Scale: 1:1987.
Highlighted:
Coincident Nodes
Coincident Elements

ARUP

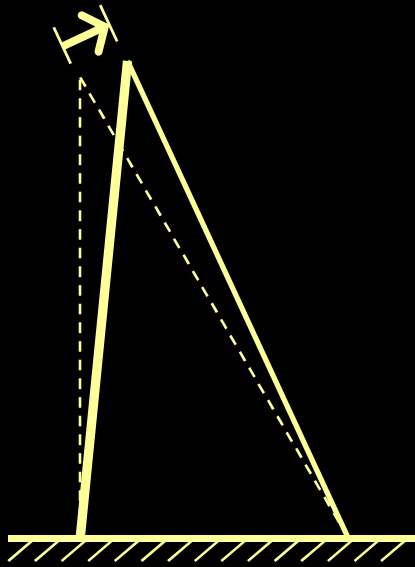
Axial shortening + sway



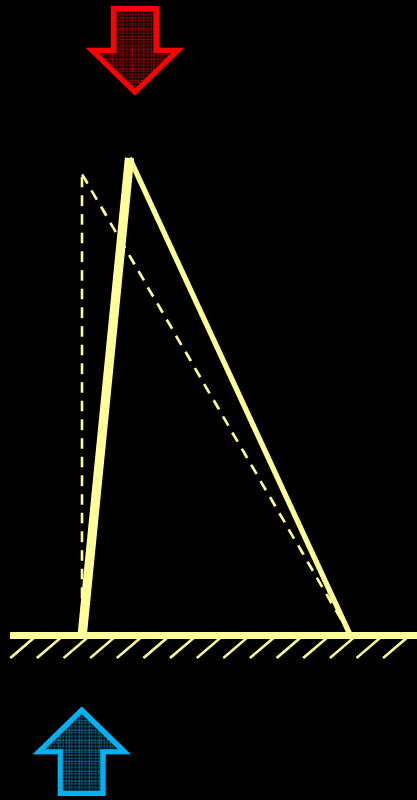
Managing movements



ARUP



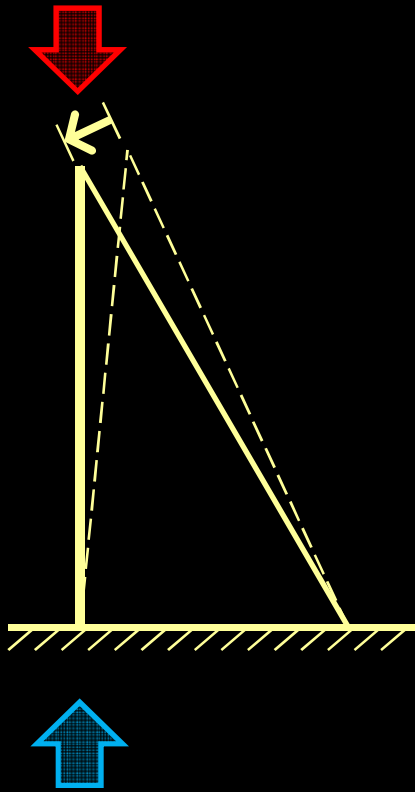
Original solution:
Pre-set the frame
(build out-of-plumb)



Original solution:
Pre-set the frame
(build out-of-plumb)

Managing movements

ARUP



Original solution:
Pre-set the frame
(build out-of-plumb)

Managing movements

ARUP

Active Alignment

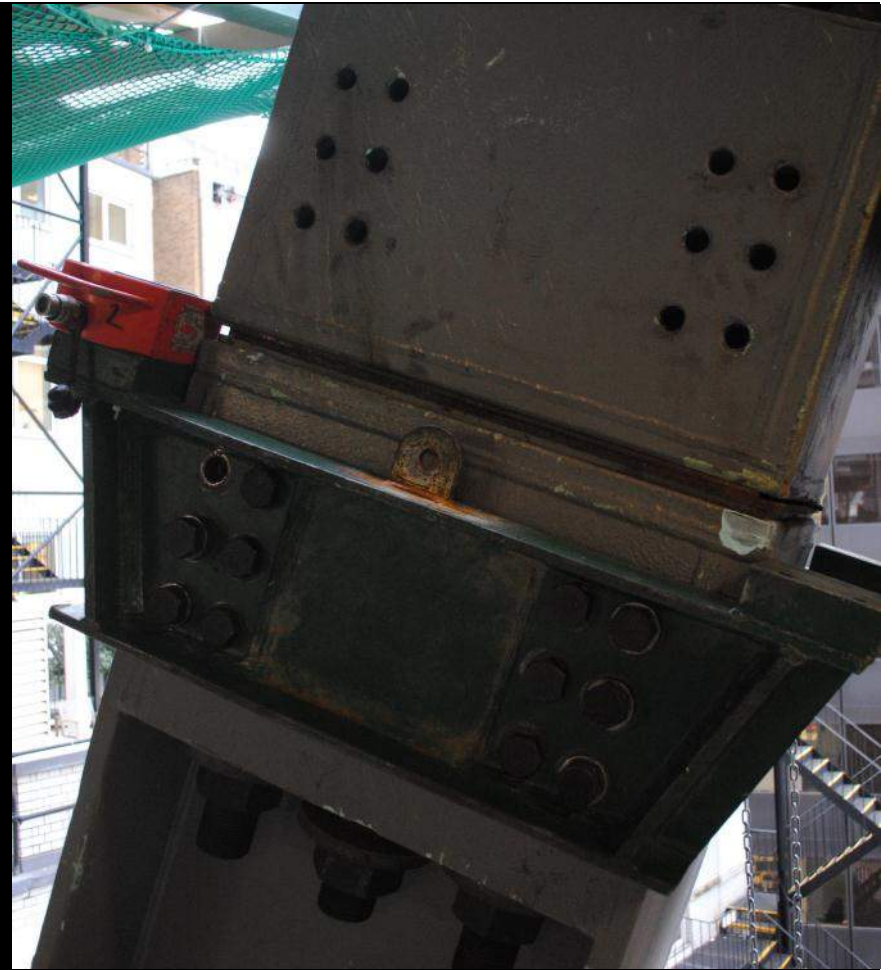
Managing movements

ARUP

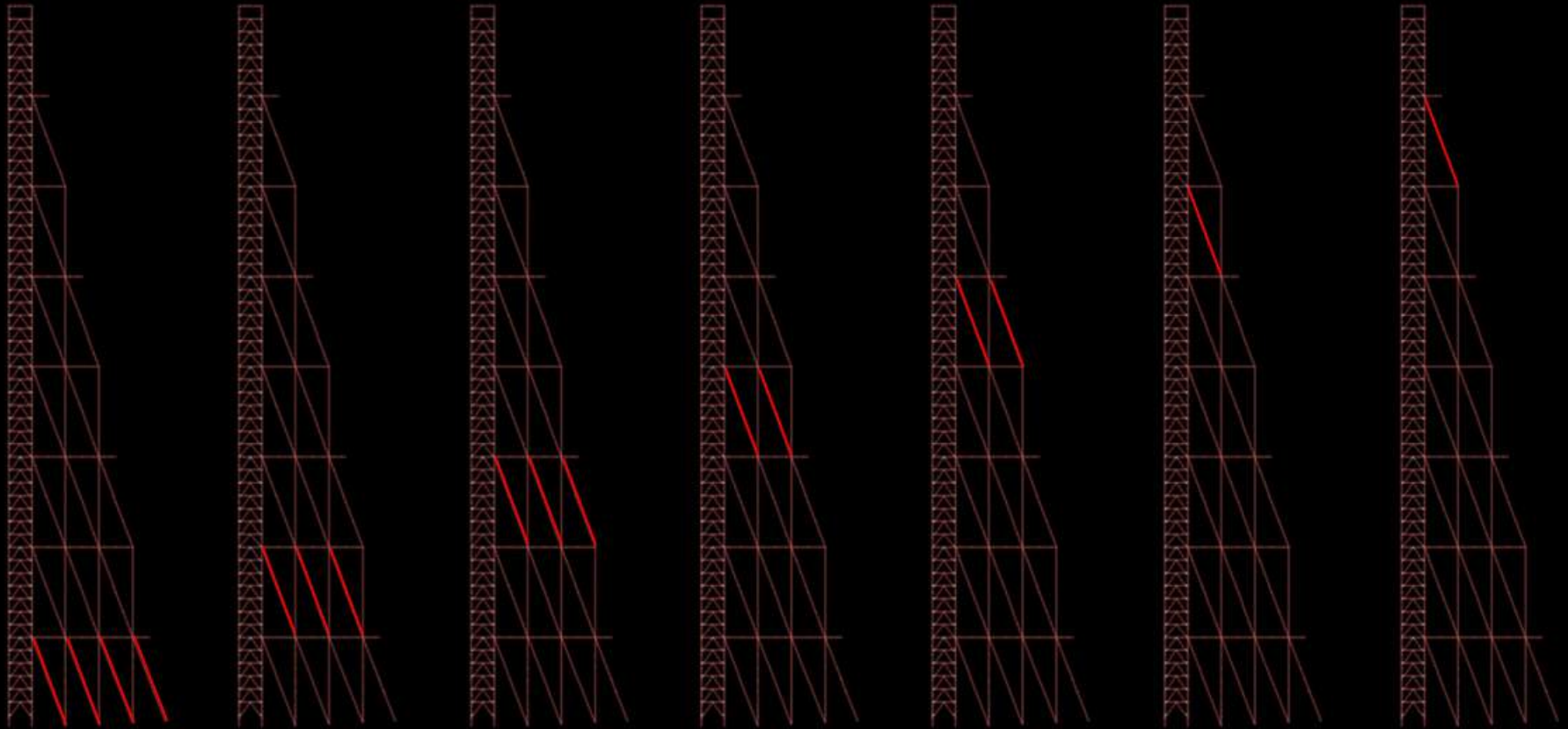




Managing movements



ARUP



AA1

AA2

AA3

AA4

AA5

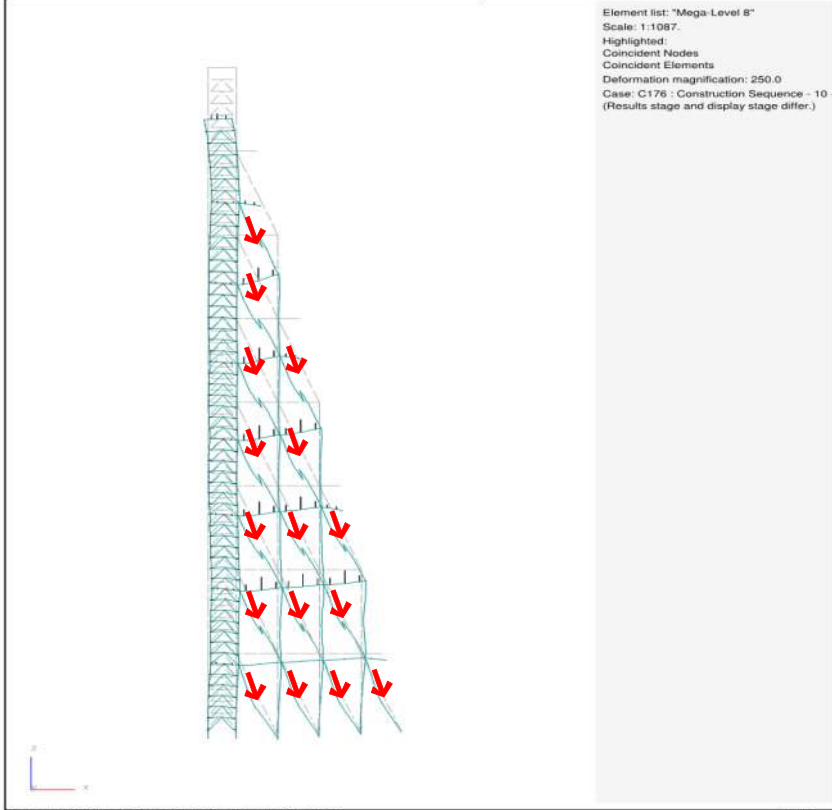
AA6

AA7

Managing movements

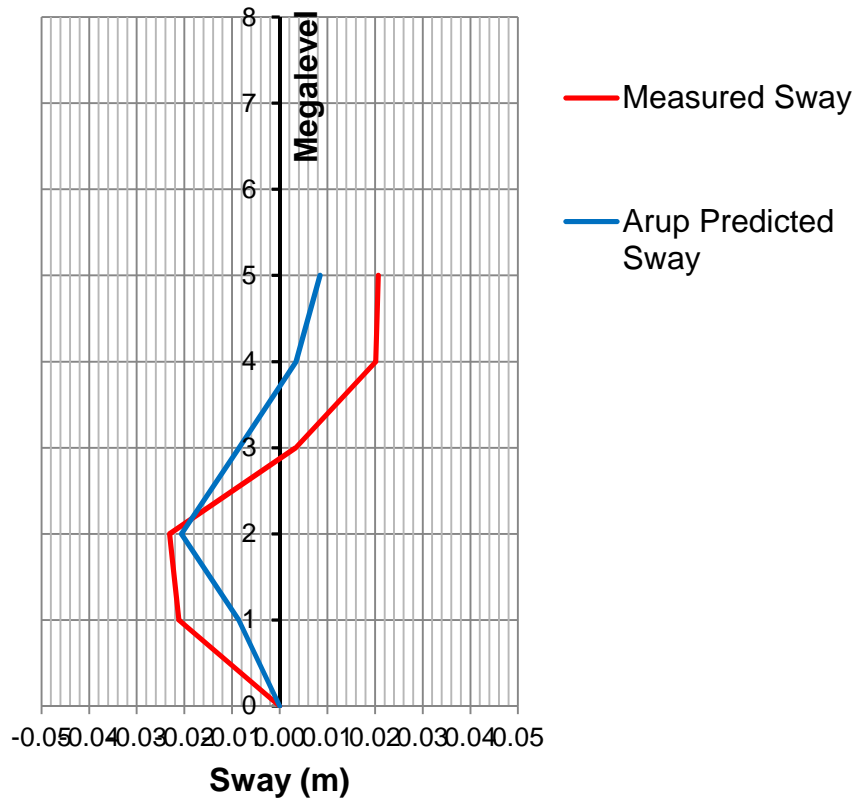
ARUP

Job No.	Sheet No.	Rev.
68502		
Org. Ref.		
Made by cm	Date 25-Nov-2011	Checked

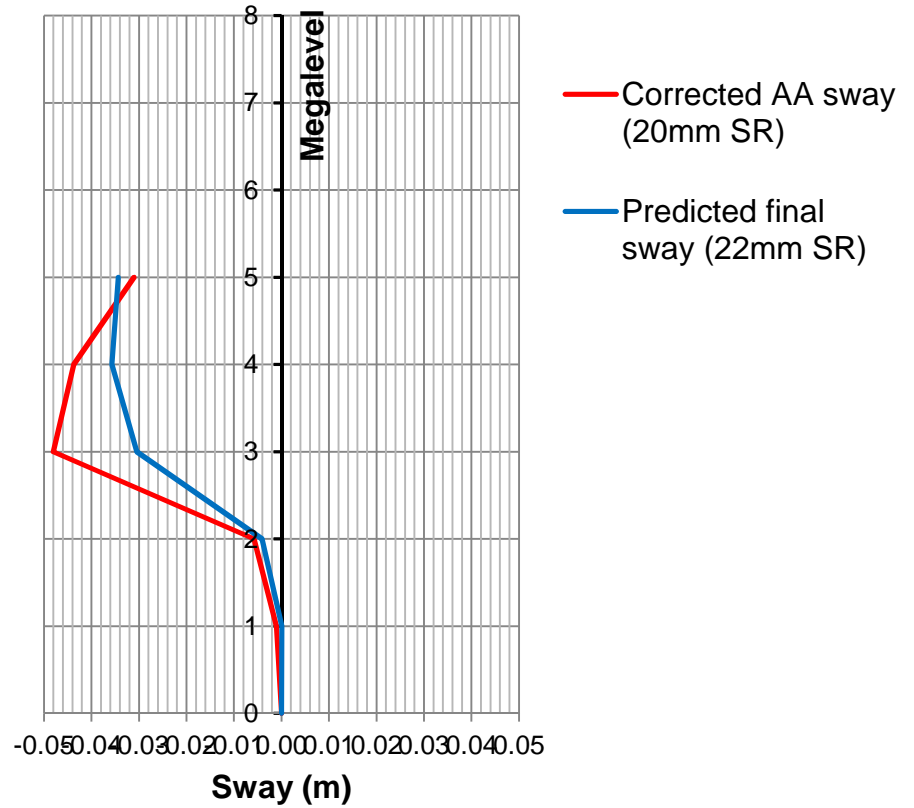


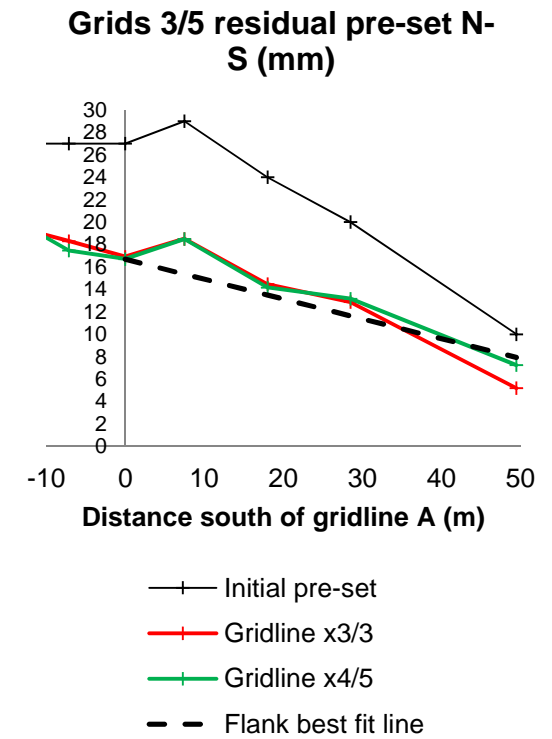
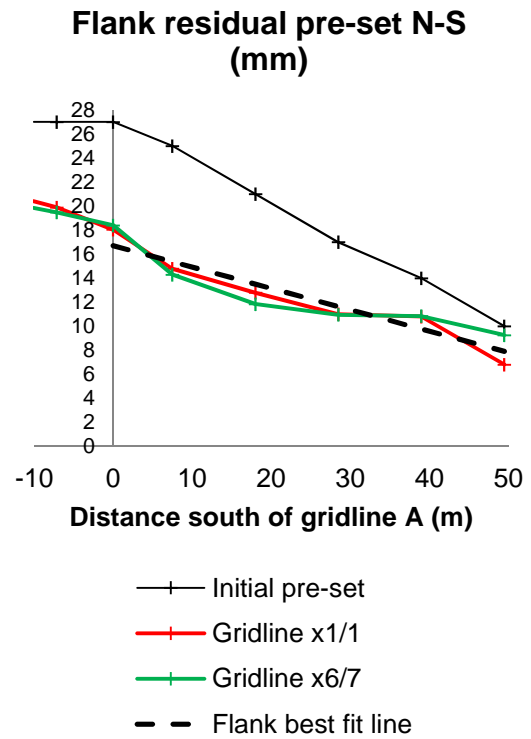
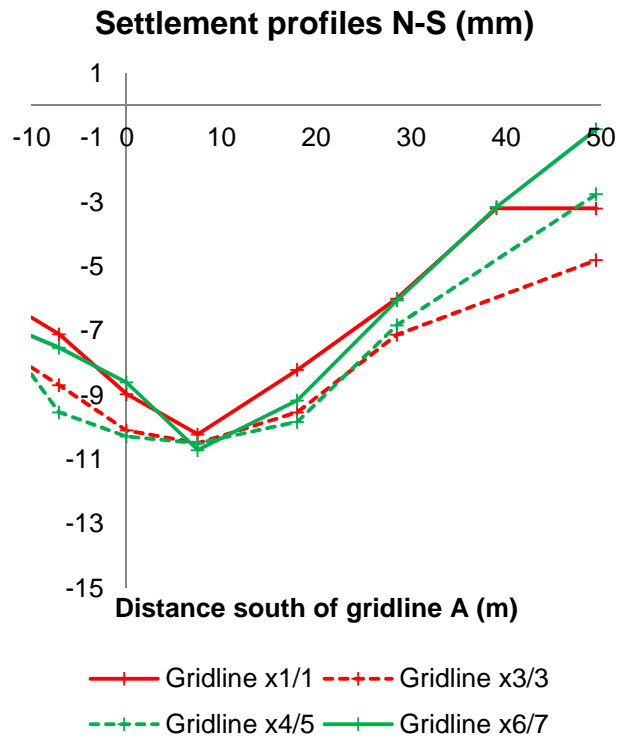
Managing movements

Sway to the north at end CS5



Sway to the north during AA3





Engineering systems

The challenge of the megaframe

Efficiency and buildability

Managing movements

Lessons learned

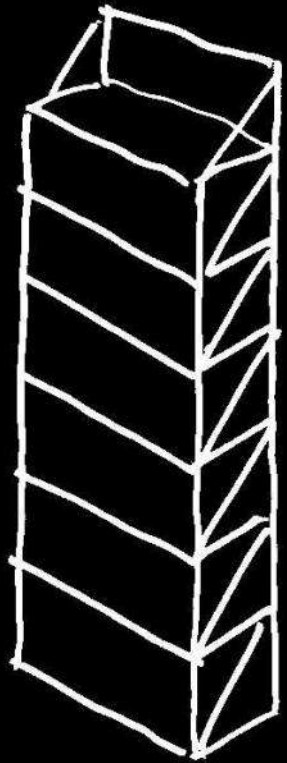
The Leadenhall Building

ARUP



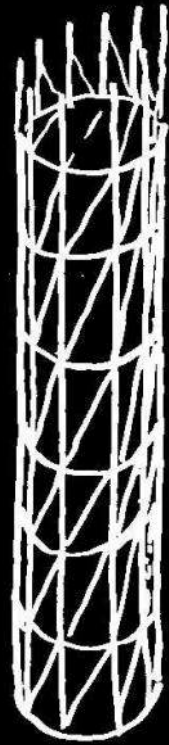
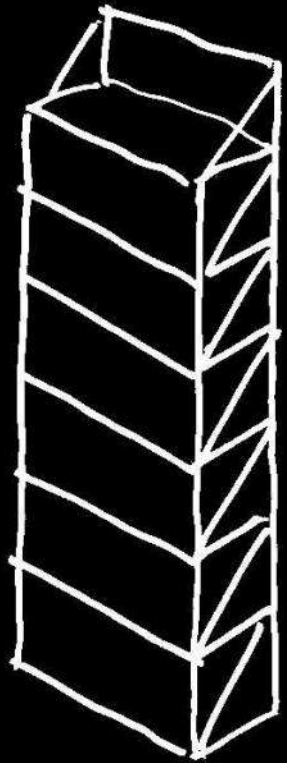
Lessons learned

ARUP



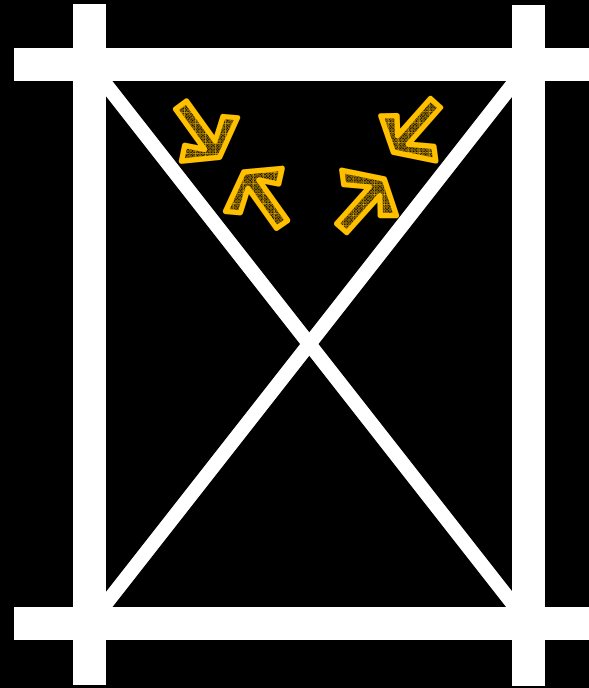
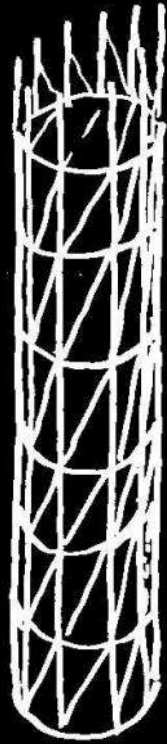
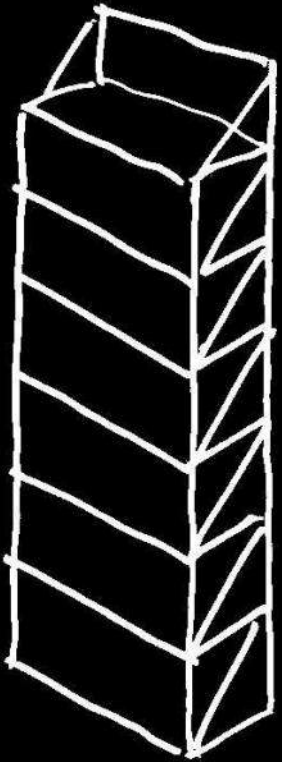
Lessons learned

ARUP



Lessons learned

ARUP



Lessons learned

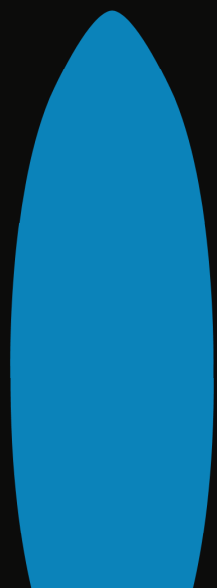
ARUP



Lessons learned

ARUP

ARUP



30 St.
Mary's Axe



112
Leadenhall



8 Canada
Square



BBVA
Mexico



Heron
Tower



Commerzbank
Tower



The
Shard