Limberlost Place: A 10-Storey Slab-Banded Structure

Robert Jackson
Partner | P.Eng, Struct.Eng, P.E., S.E., C.Eng., MIStructE

AGENDA

Design

Structural Testing

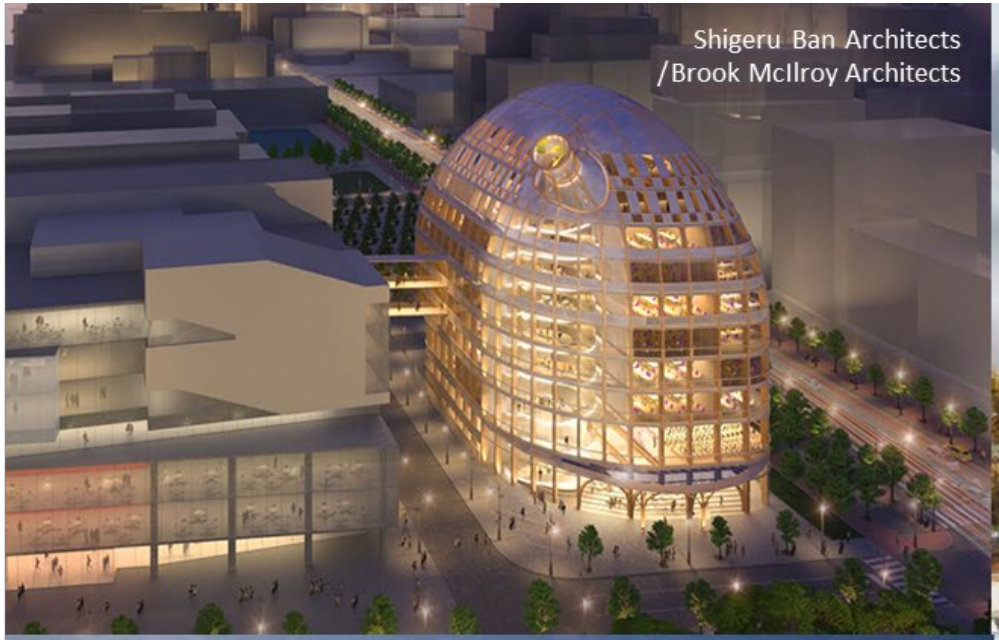
Fabrication & Construction

AGENDA

Design

Structural Testing

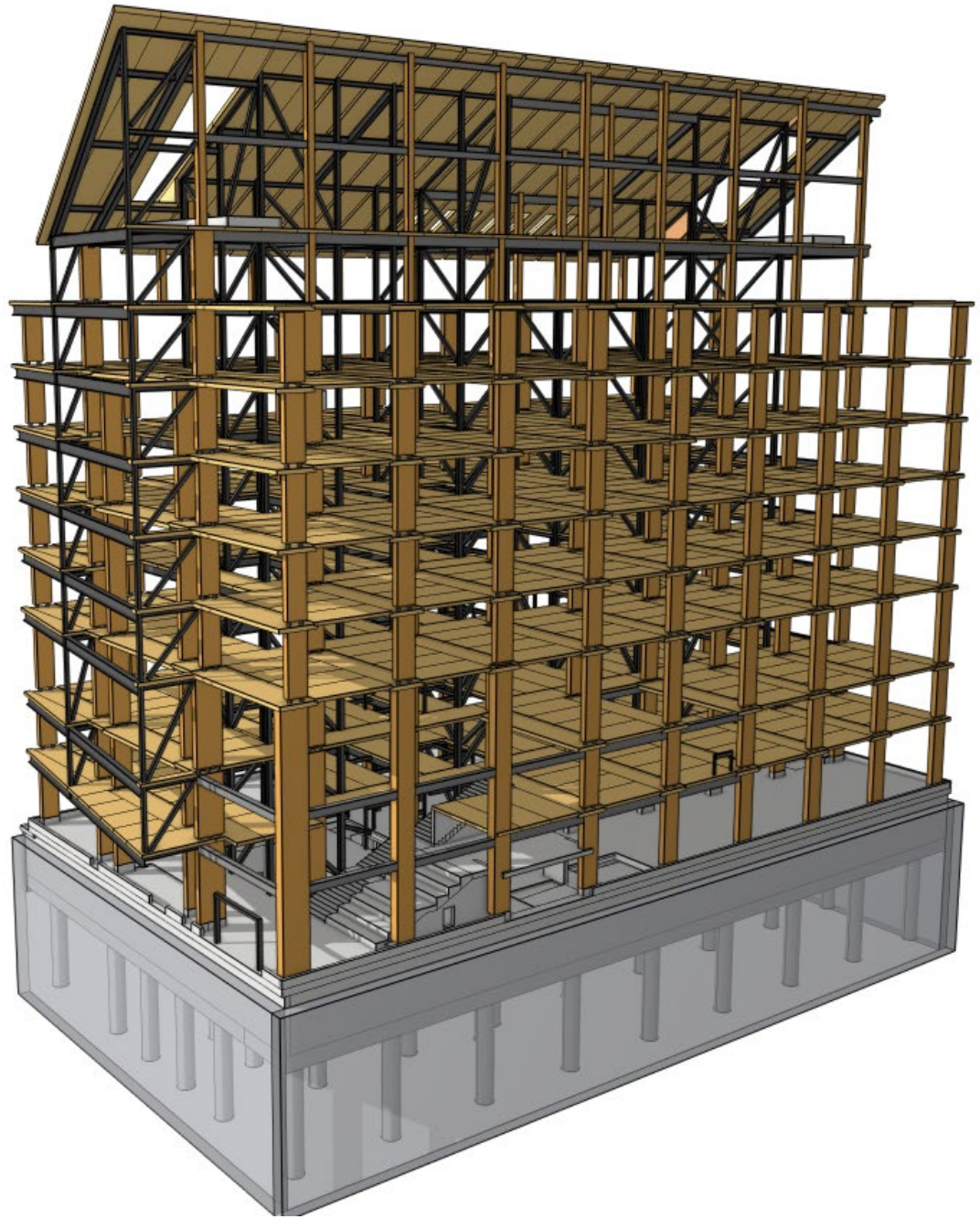
Fabrication & Construction

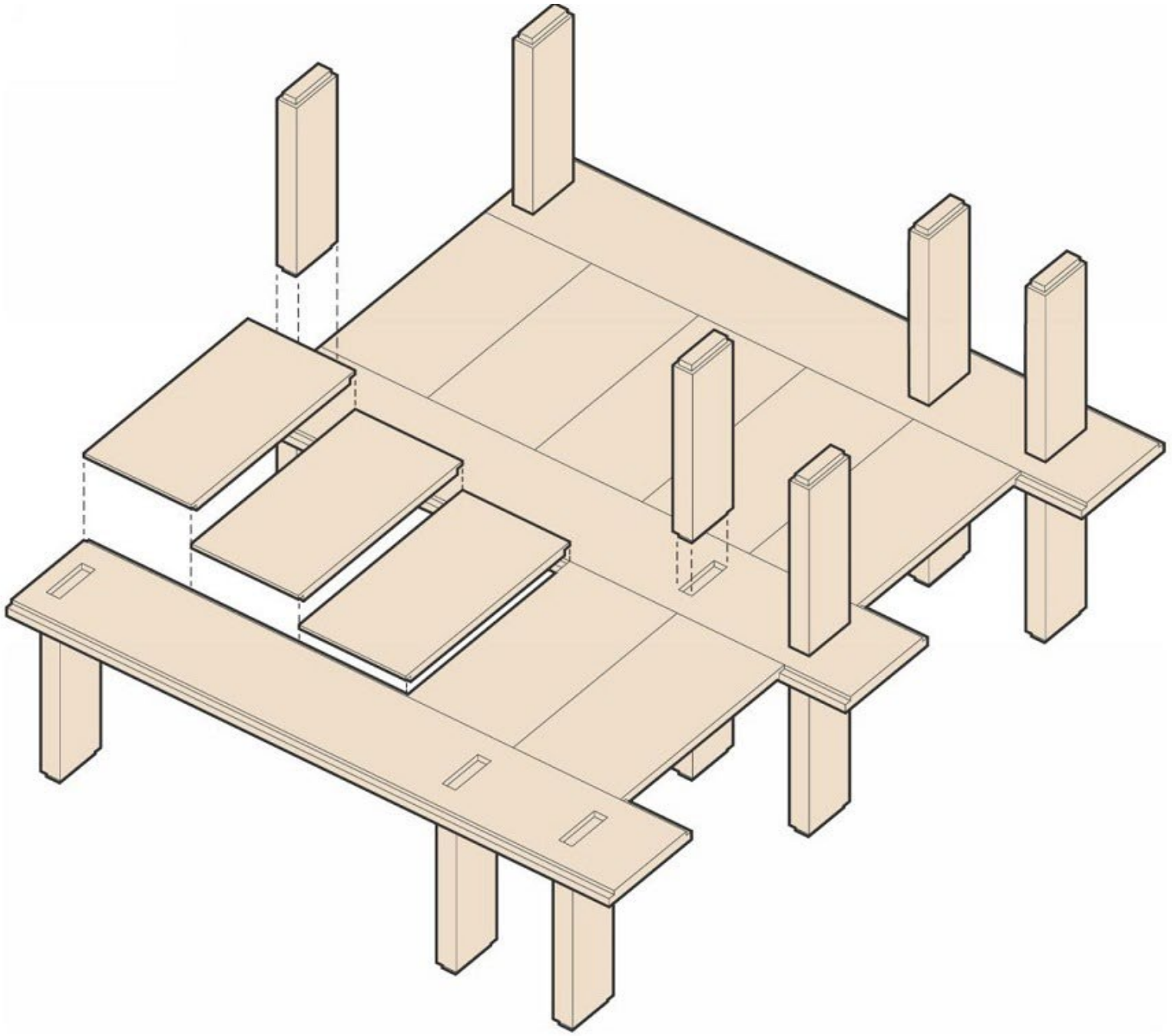

Shigeru Ban Architects
/Brook McIlroy Architects

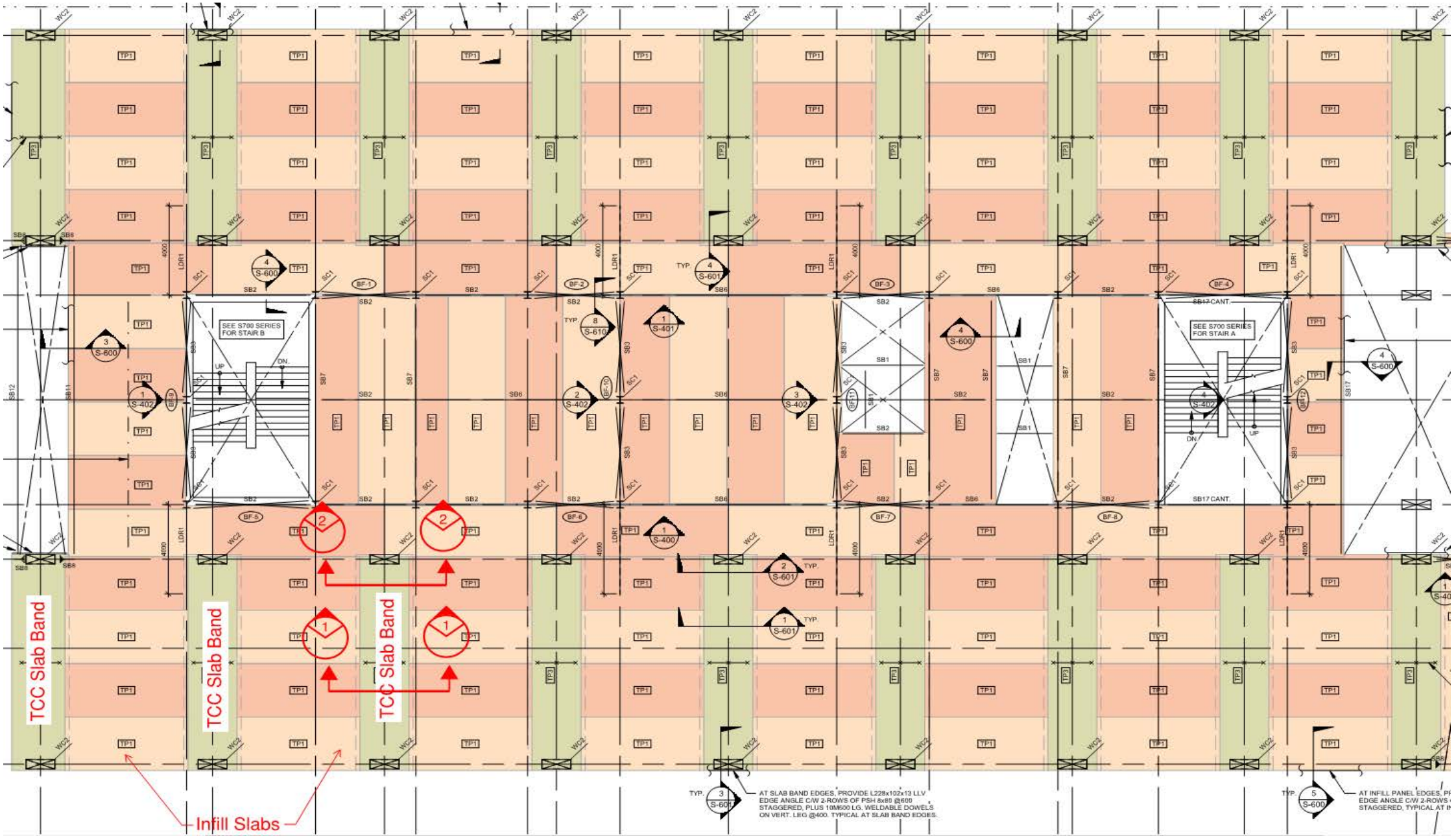
Provencher Roy
/Turner Fleischer

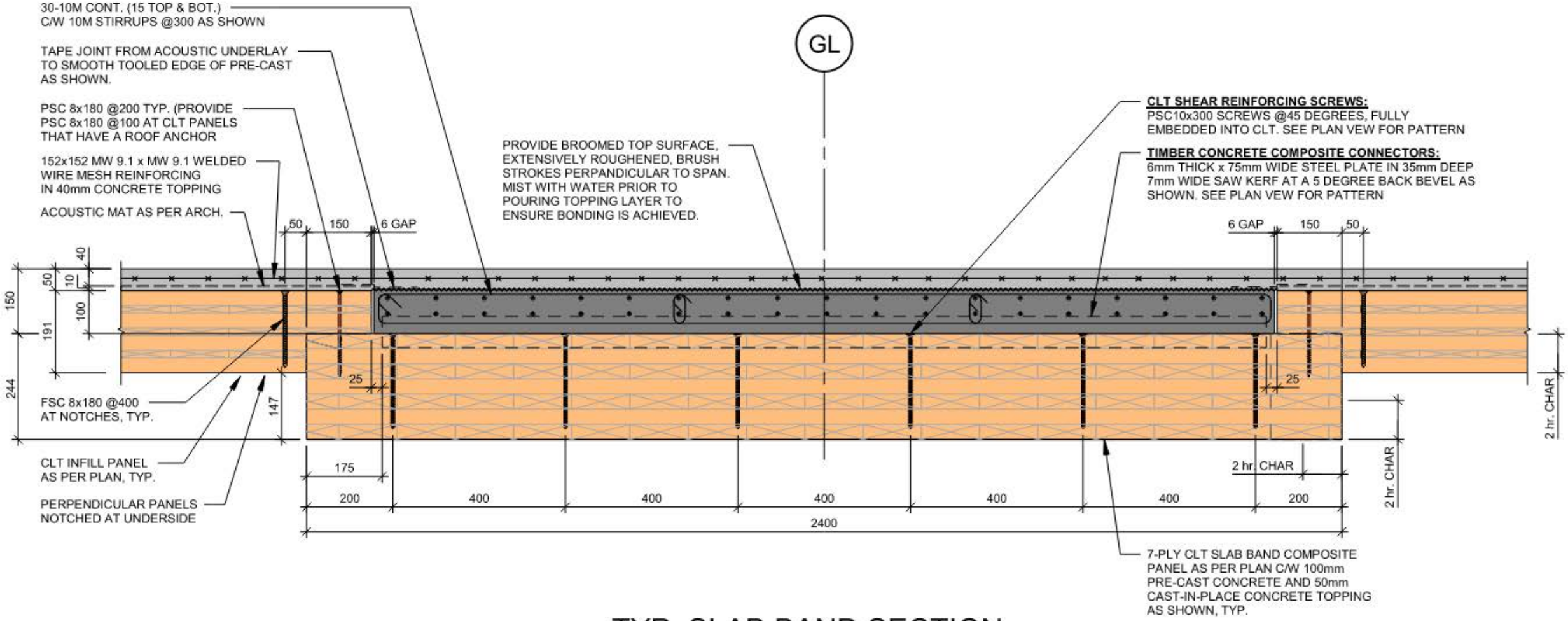
Patkau
/MJMA

Moriyama & Teshima Architects
/Acton Ostry Architects

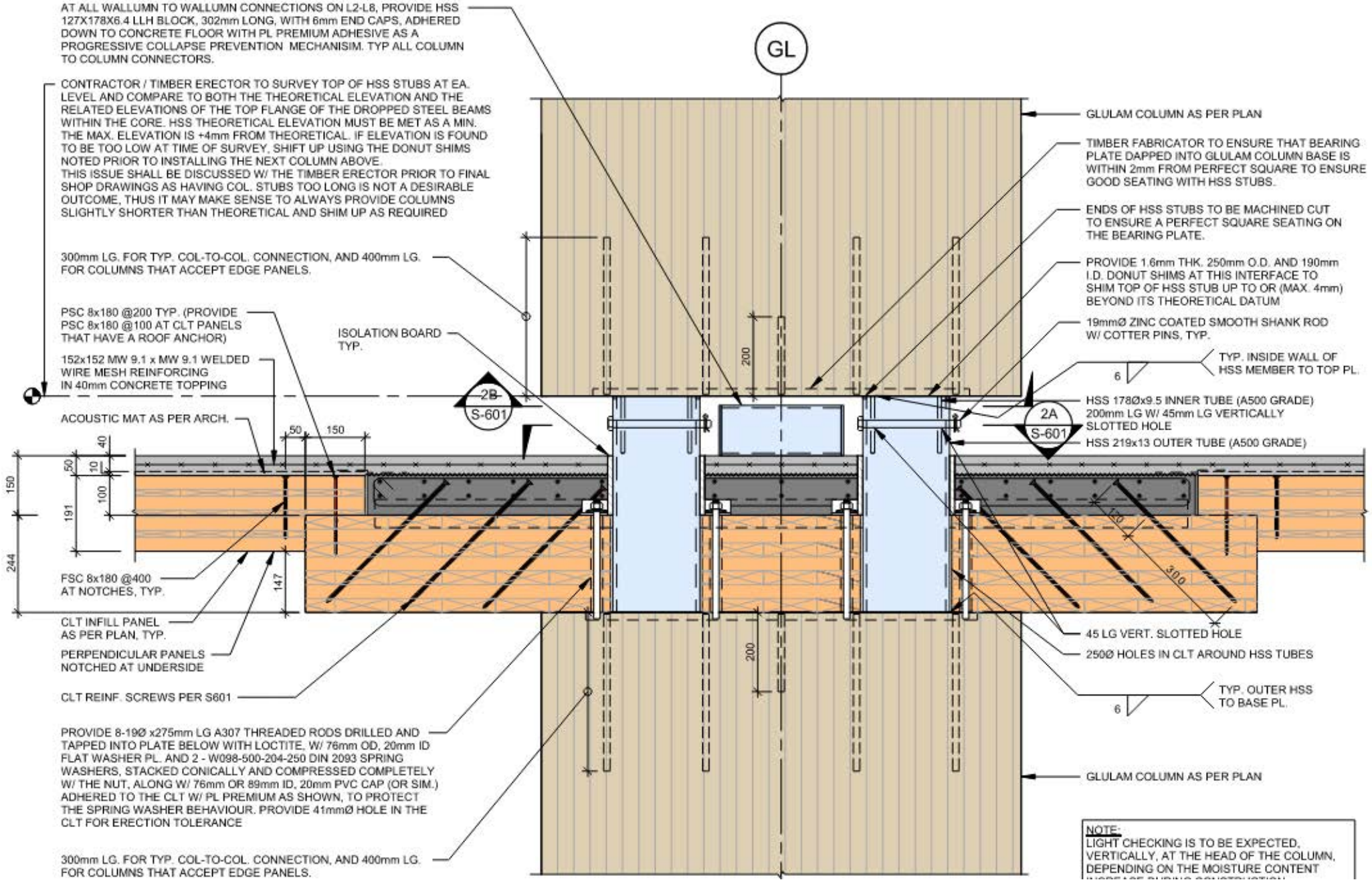


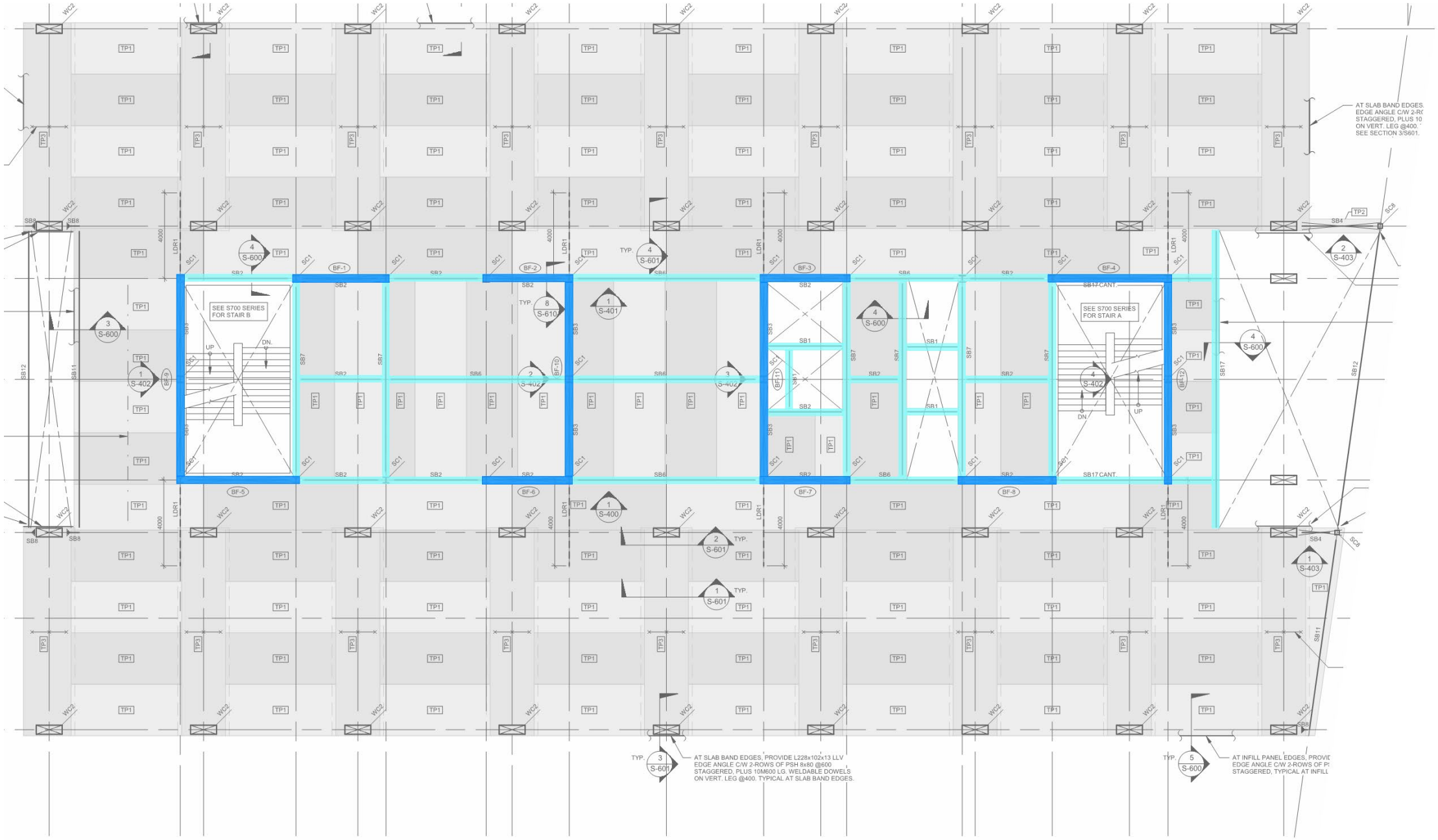



TCC Slab Band
TCC Slab Band
TCC Slab Band
Infill Slabs
SEE S700 SERIES FOR STAIR B
SEE S700 SERIES FOR STAIR A
AT SLAB BAND EDGES, PROVIDE L228x102x13 LLV EDGE ANGLE C/W 2-ROWS OF PSH 8x80 @600 STAGGERED, PLUS 10M500 LG. WELDABLE DOWELS ON VERT. LEG @400. TYPICAL AT SLAB BAND EDGES.



TYP. SLAB BAND SECTION


AT ALL WALLUMN TO WALLUMN CONNECTIONS ON L2-L8, PROVIDE HSS 127X178X6.4 LLH BLOCK, 302mm LONG, WITH 6mm END CAPS, ADHERED DOWN TO CONCRETE FLOOR WITH PL PREMIUM ADHESIVE AS A PROGRESSIVE COLLAPSE PREVENTION MECHANISIM. TYP ALL COLUMN TO COLUMN CONNECTORS.
CONTRACTOR / TIMBER ERECTOR TO SURVEY TOP OF HSS STUBS AT EA. LEVEL AND COMPARE TO BOTH THE THEORETICAL ELEVATION AND THE RELATED ELEVATIONS OF THE TOP FLANGE OF THE DROPPED STEEL BEAMS WITHIN THE CORE. HSS THEORETICAL ELEVATION MUST BE MET AS A MIN. THE MAX. ELEVATION IS +4mm FROM THEORETICAL. IF ELEVATION IS FOUND TO BE TOO LOW AT TIME OF SURVEY, SHIFT UP USING THE DONUT SHIMS NOTED PRIOR TO INSTALLING THE NEXT COLUMN ABOVE.
THIS ISSUE SHALL BE DISCUSSED W/ THE TIMBER ERECTOR PRIOR TO FINAL SHOP DRAWINGS AS HAVING COL. STUBS TOO LONG IS NOT A DESIRABLE OUTCOME, THUS IT MAY MAKE SENSE TO ALWAYS PROVIDE COLUMNS SLIGHTLY SHORTER THAN THEORETICAL AND SHIM UP AS REQUIRED
300mm LG. FOR TYP. COL-TO-COL. CONNECTION, AND 400mm LG. FOR COLUMNS THAT ACCEPT EDGE PANELS.
PSC 8x180 @200 TYP. (PROVIDE PSC 8x180 @100 AT CLT PANELS THAT HAVE A ROOF ANCHOR)
152x152 MW 9.1 x MW 9.1 WELDED WIRE MESH REINFORCING IN 40mm CONCRETE TOPPING
ACOUSTIC MAT AS PER ARCH.
FSC 8x180 @400 AT NOTCHES, TYP.
CLT INFILL PANEL AS PER PLAN, TYP.
PERPENDICULAR PANELS NOTCHED AT UNDERSIDE
CLT REINF. SCREWS PER S601
PROVIDE 8-19Ø x275mm LG A307 THREADED RODS DRILLED AND TAPPED INTO PLATE BELOW WITH LOCTITE, W/ 76mm OD, 20mm ID FLAT WASHER PL. AND 2 - W098-500-204-250 DIN 2093 SPRING WASHERS, STACKED CONICALLY AND COMPRESSED COMPLETELY W/ THE NUT, ALONG W/ 76mm OR 89mm ID, 20mm PVC CAP (OR SIM.) ADHERED TO THE CLT W/ PL PREMIUM AS SHOWN, TO PROTECT THE SPRING WASHER BEHAVIOUR. PROVIDE 41mmØ HOLE IN THE CLT FOR ERECTION TOLERANCE
300mm LG. FOR TYP. COL-TO-COL. CONNECTION, AND 400mm LG. FOR COLUMNS THAT ACCEPT EDGE PANELS.
ISOLATION BOARD TYP.
GL
GLULAM COLUMN AS PER PLAN
TIMBER FABRICATOR TO ENSURE THAT BEARING PLATE DAPPED INTO GLULAM COLUMN BASE IS WITHIN 2mm FROM PERFECT SQUARE TO ENSURE GOOD SEATING WITH HSS STUBS.
ENDS OF HSS STUBS TO BE MACHINED CUT TO ENSURE A PERFECT SQUARE SEATING ON THE BEARING PLATE.
PROVIDE 1.6mm THK. 250mm O.D. AND 190mm I.D. DONUT SHIMS AT THIS INTERFACE TO SHIM TOP OF HSS STUB UP TO OR (MAX. 4mm) BEYOND ITS THEORETICAL DATUM
19mmØ ZINC COATED SMOOTH SHANK ROD W/ COTTER PINS, TYP.
TYP. INSIDE WALL OF HSS MEMBER TO TOP PL.
HSS 178Øx9.5 INNER TUBE (A500 GRADE) 200mm LG W/ 45mm LG VERTICALLY SLOTTED HOLE
HSS 219x13 OUTER TUBE (A500 GRADE)
45 LG VERT. SLOTTED HOLE
250Ø HOLES IN CLT AROUND HSS TUBES
TYP. OUTER HSS TO BASE PL.
GLULAM COLUMN AS PER PLAN
2B S-601
2A S-601
6
6
200
200
50
150
40
50
10
100
150
191
244
147
120
300
NOTE:
LIGHT CHECKING IS TO BE EXPECTED, VERTICALLY, AT THE HEAD OF THE COLUMN, DEPENDING ON THE MOISTURE CONTENT


SEE S700 SERIES FOR STAIR B
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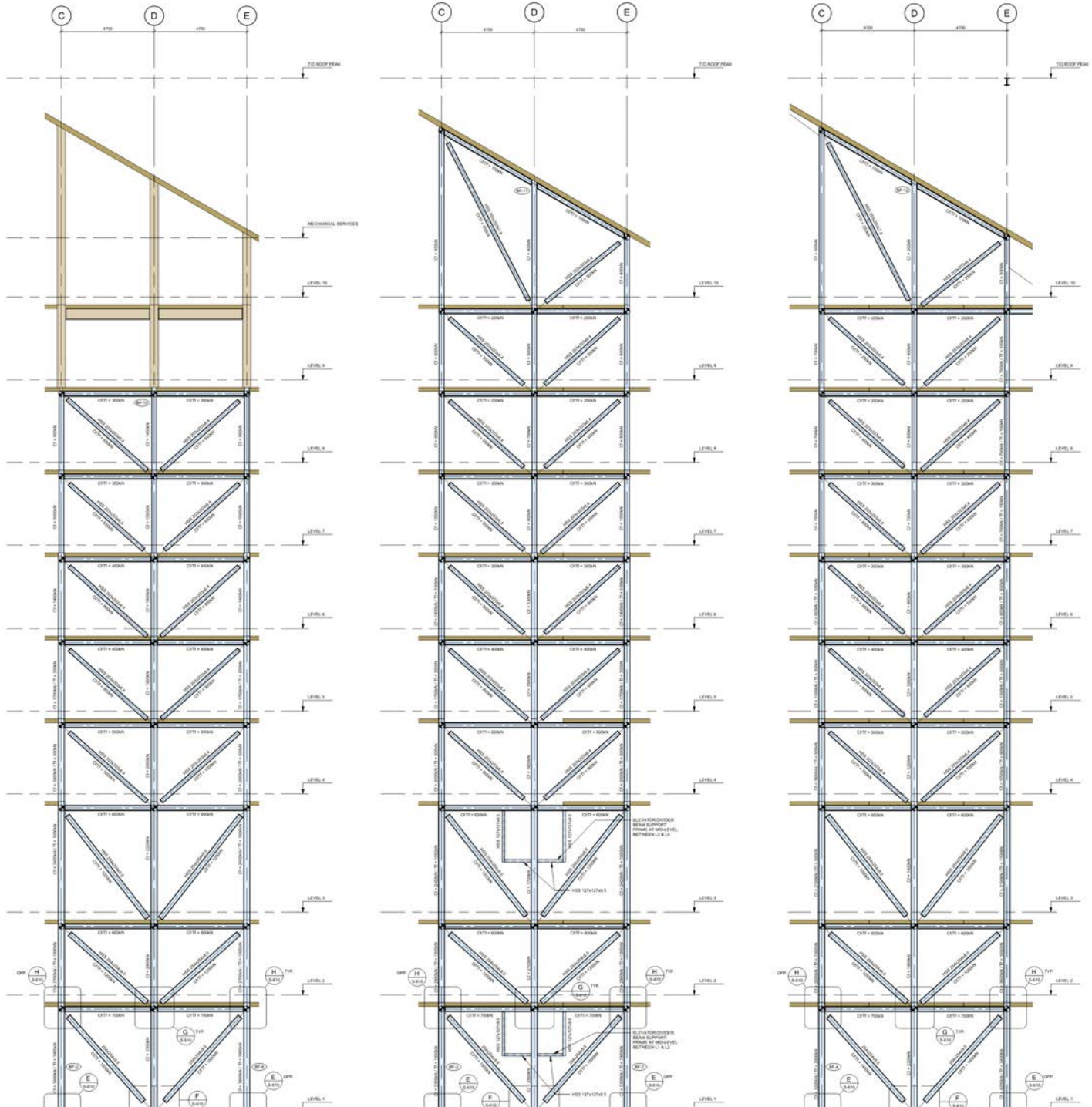
AT SLAB BAND EDGES, PROVIDE L228x102x13 LLV EDGE ANGLE C/W 2-ROWS OF PSH 8x80 @600 STAGGERED, PLUS 10M600 LG. WELDABLE DOWELS ON VERT. LEG @400. TYPICAL AT SLAB BAND EDGES.
AT SLAB BAND EDGES. EDGE ANGLE C/W 2-RO STAGGERED, PLUS 10 ON VERT. LEG @400. SEE SECTION 3/S601.
AT INFILL PANEL EDGES, PROVIE EDGE ANGLE C/W 2-ROWS OF P STAGGERED, TYPICAL AT INFILL


C
D
E
T/O ROOF PEAK
MECHANICAL SERVICES
LEVEL 10
LEVEL 9
LEVEL 8
LEVEL 7
LEVEL 6
LEVEL 5
LEVEL 4
LEVEL 3
LEVEL 2
LEVEL 1
ELEVATOR DIVIDER BEAM SUPPORT FRAME AT MID-LEVEL BETWEEN L1 & L2
HSS 127x127x6.3

AGENDA

Design

Structural Testing

Fabrication & Construction

TESTING GOALS

- Determine out-of-plane shear capacity of TCC
- Determine stiffness and capacity of various shear flow connector options
- Determine ultimate capacity of TCC assembly for the project
- Validate stiffness of TCC bands for model calibration & vibration analysis

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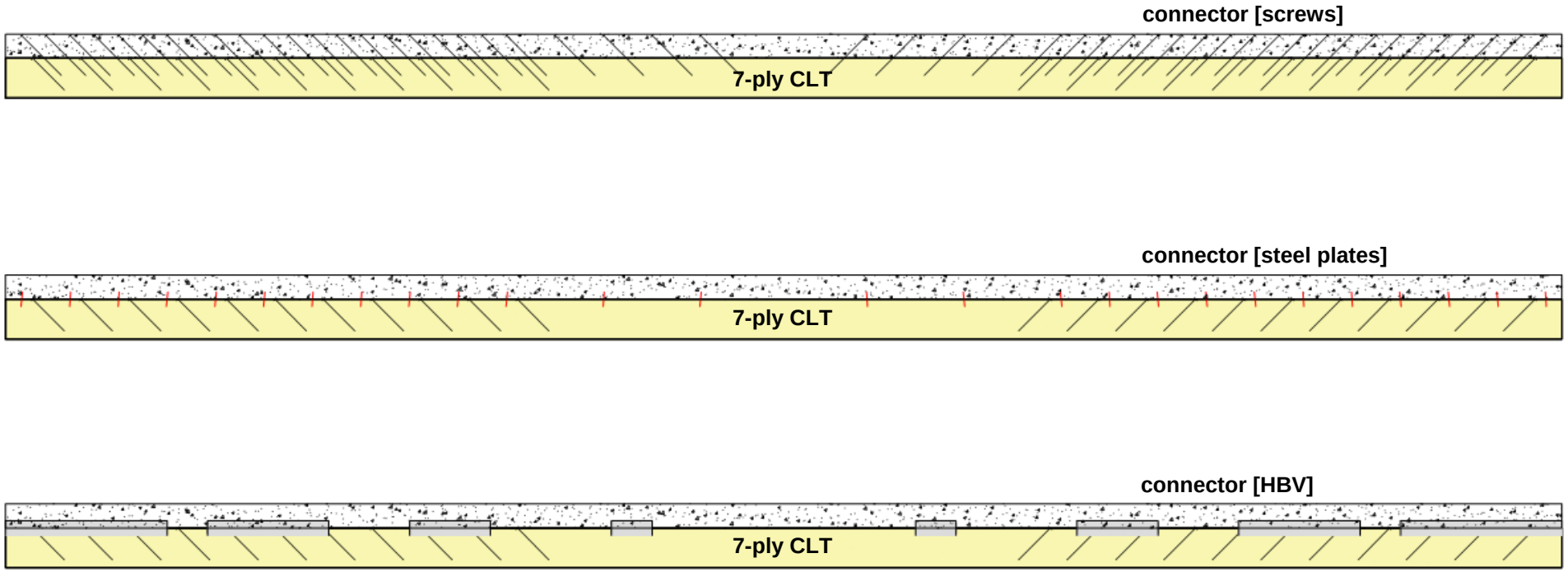
Fast + Epp

Natural Resources Canada | Ressources naturelles Canada

Canada

STRUCTURLAM

Intelligence In Wood


connector [screws]
7-ply CLT
connector [steel plates]
7-ply CLT
connector [HBV]
7-ply CLT

BY STRUCTURLAM
STRUCTURLAM.COM
BY STRUCTURLAM
STRUCTURLAM.COM
Structurlam Mass Timber Corporation
STRUCTURLAM
200131 - 26670 Arbour Test Panels - PBA
CODE - Load 1 - 2
1000.000 x 300.000 x 245.000 mm
FP101 43370
Load1 Bundle4 PCS4
101

STRUCTURAL TESTING PROGRAM

Series	Description	Connector Type	Designation	Test Type	# of tests	L [mm]	L_o [mm]	b_c [mm]	b_t [mm]
1	Small scale Test 1 [See Table 6]	steel plates	SC_T1	Shear	6	1000	-	300	300
	Small scale Test 2 [See Table 6]	steel plates	SC_T2	Shear	6	1000	-	300	300
	Small scale Test 3 [See Table 6]	steel plates	SC_T3	Shear	6	1000	-	300	300
2	Half scale, Raw CLT	-	HS_UR_CLT	Bending	4	5030	4170	2200	2400
	Half Scale, Half Reinforced CLT Panels	-	HS_HR_CLT	Bending	4	5030	4170	2200	2400
	Half Scale, Full Reinforced CLT Panels	-	HS_FR_CLT	Bending	4	5030	4170	2200	2400
3	Half scale, Raw CLT w/ Type 1 TCC	screws	HS_UR_CLT_TCC_I	Bending	2	5030	4170	2200	2400
	Half Scale, Half Reinforced CLT Panels w/ Type 1 TCC	screws	HS_HR_CLT_TCC_I	Bending	2	5030	4170	2200	2400
	Half Scale, Full Reinforced CLT Panels w/ Type 1 TCC	screws	HS_FR_CLT_TCC_I	Bending	2	5030	4170	2200	2400
4	Half scale, Raw CLT w/ Type 2 TCC	steel plates	HS_UR_CLT_TCC_II	Bending	2	5030	4170	2200	2400
	Half Scale, Half Reinforced CLT Panels w/ Type 2 TCC	steel plates	HS_HR_CLT_TCC_II	Bending	2	5030	4170	2200	2400
	Half Scale, Full Reinforced CLT Panels w/ Type 2 TCC	steel plates	HS_FR_CLT_TCC_II	Bending	2	5030	4170	2200	2400
5	Half scale, Raw CLT w/ Type 3 TCC	HBV	HS_UR_CLT_TCC_III	Bending	2	5030	4170	2200	2400
	Half Scale, Half Reinforced CLT Panels w/ Type 3 TCC	HBV	HS_HR_CLT_TCC_III	Bending	2	5030	4170	2200	2400
	Half Scale, Full Reinforced CLT Panels w/ Type 3 TCC	HBV	HS_FR_CLT_TCC_III	Bending	2	5030	4170	2200	2400
6	Full Scale, Half Reinforced CLT Panels w/ Type 1 TCC	screws	FS_HR_CLT_TCC_I	Bending	3	9630	8770	2200	2400
	Full Scale, Half Reinforced CLT Panels w/ Type 2 TCC	steel plates	FS_HR_CLT_TCC_II	Bending	3	9630	8770	2200	2400
	Full Scale, Half Reinforced CLT Panels w/ Type 3 TCC	HBV	FS_HR_CLT_TCC_III	Bending	3	9630	8770	2200	2400
7	Full Scale, Half Reinforced CLT Panels w/ Type 1 TCC	screws	FS_HR_CLT_TCC_I	Torsion	1	9630	8770	2200	2400
	Full Scale, Half Reinforced CLT Panels w/ Type 2 TCC	steel plates	FS_HR_CLT_TCC_II	Torsion	1	9630	8770	2200	2400
	Full Scale, Half Reinforced CLT Panels w/ Type 3 TCC	HBV	FS_HR_CLT_TCC_III	Torsion	1	9630	8770	2200	2400

Note: SC = Small Scale; FS = Full Scale; HS = Half Scale; UR = Unreinforced or Raw; HR = Half Reinforced; FR = Full Reinforced CLT = Cross-Laminated Timber; TCC = Timber Concrete Composite

L = total span, L_0 = clear span, b_c = width of concrete top, b_t = width of CLT panel

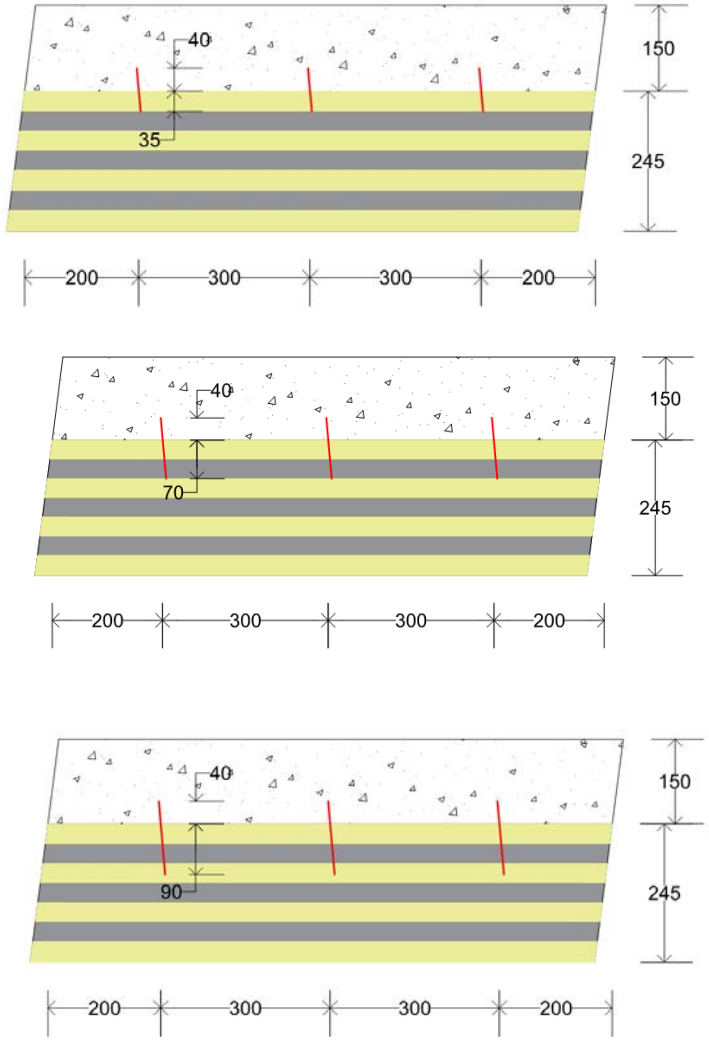
18 Small Scale Tests

30 Half Scale Tests

12 Full Scale Tests

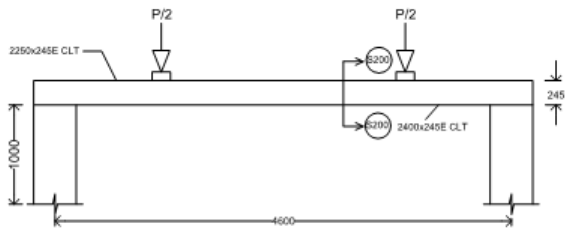
60 Total Tests

SMALL SCALE TESTS

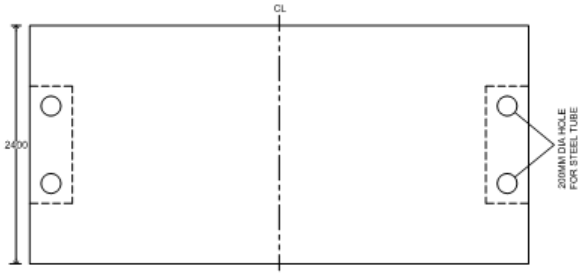


HALF SCALE TESTS

SERIES 2A: UNREINFORCED CLT

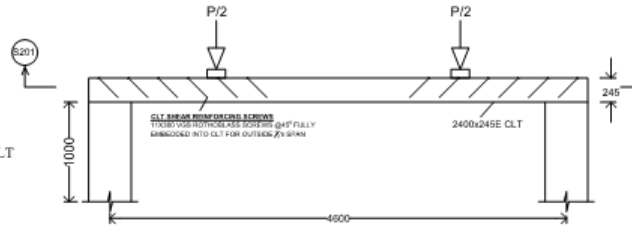


SERIES 2A:RAW UNREINFORCED CLT

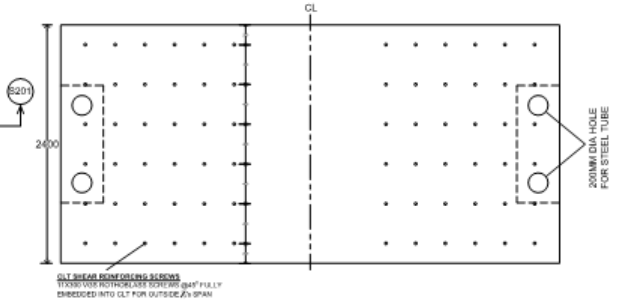


S200 PLAN VIEW OF UNREINFORCED CLT

SERIES 2B: HALF REINFORCED CLT

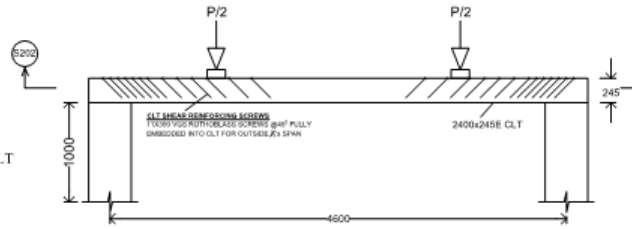


SERIES 2A: RAW HALF REINFORCED CLT

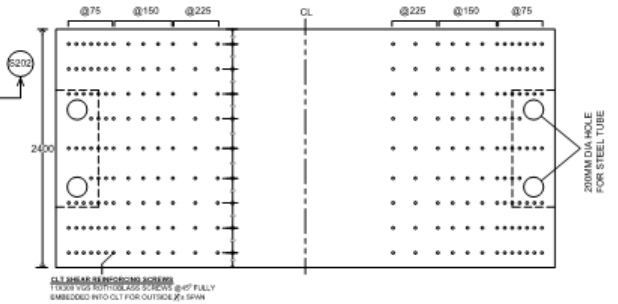


S201 PLAN VIEW OF HALF SCREWS REINFORCED CLT

SERIES 2C: FULL REINFORCED CLT

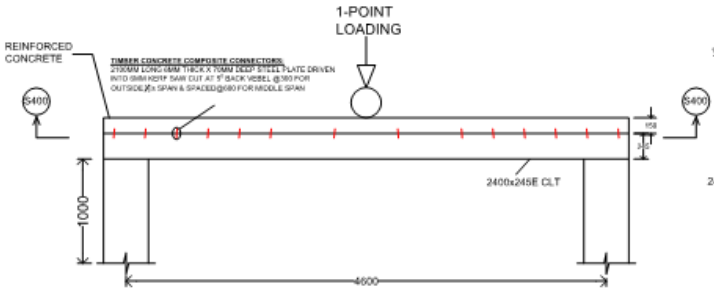


SERIES 2A: RAW FULL REINFORCED CLT

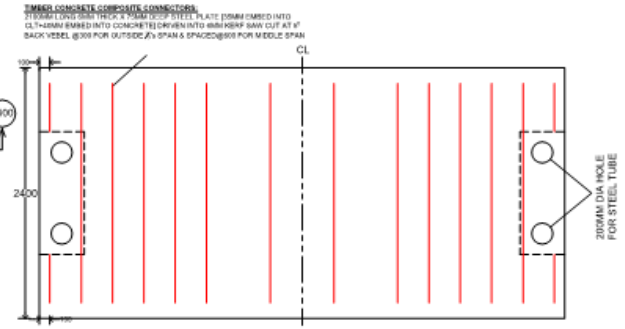


S202 PLAN VIEW OF FULL SCREWS REINFORCED CLT

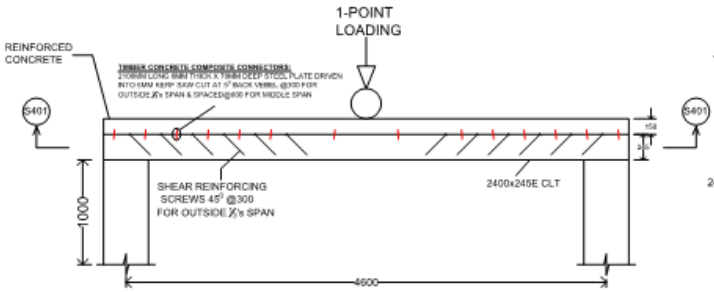
HALF SCALE TESTS



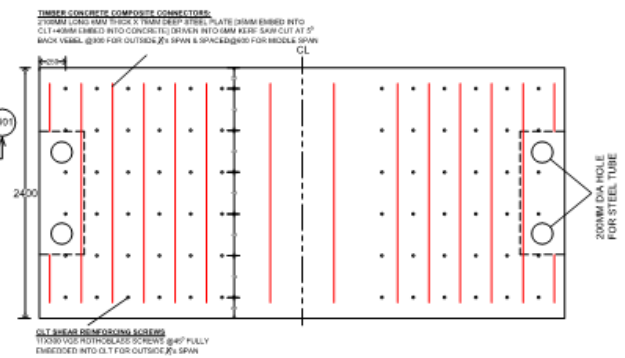
SERIES 4A:TCC TYPE II WITH UNREINFORCED CLT



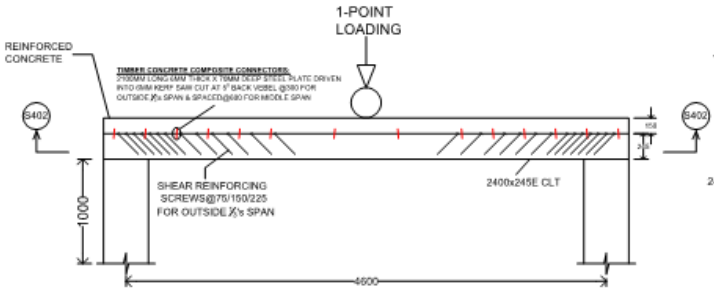
S402 PLAN VIEW OF TYPE II TCC WITH STEEL PLATE



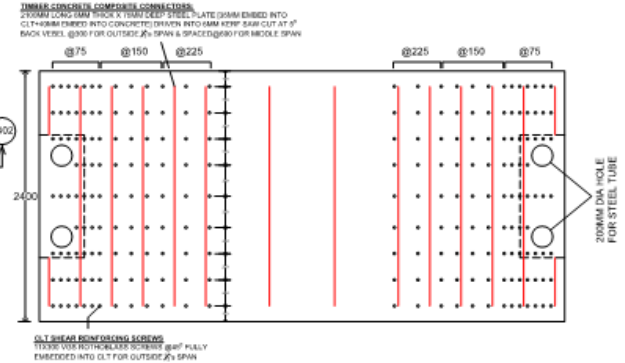
SERIES 4B: TCC TYPE II WITH HALF-REINFORCED CLT



S401 PLAN VIEW OF TYPE II TCC WITH HALF SCREWS REINFORCED CLT

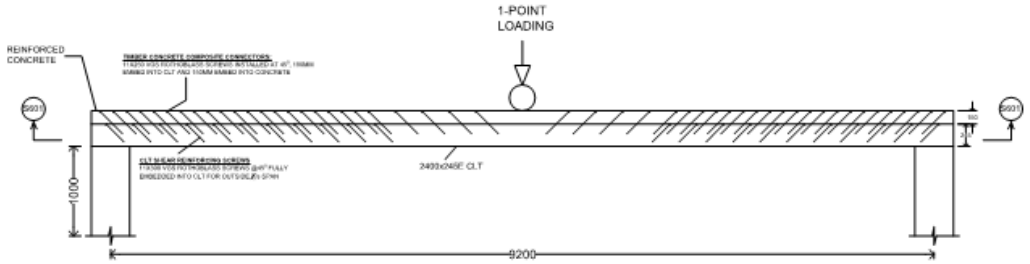


SERIES 4C: TCC TYPE II WITH FULL-REINFORCED CLT

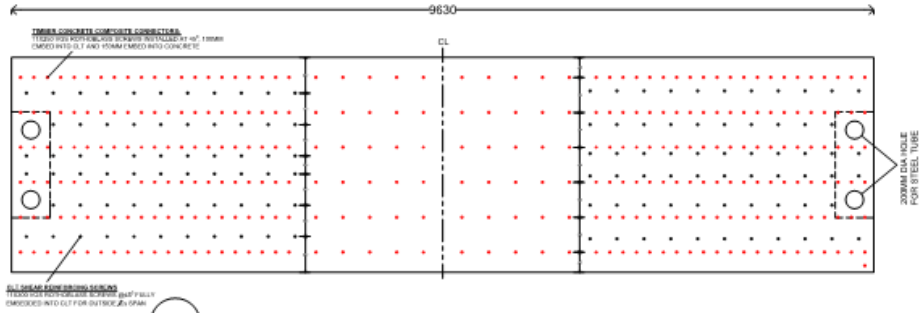


S402 PLAN VIEW OF TYPE II TCC WITH FULL SCREWS REINFORCED CLT

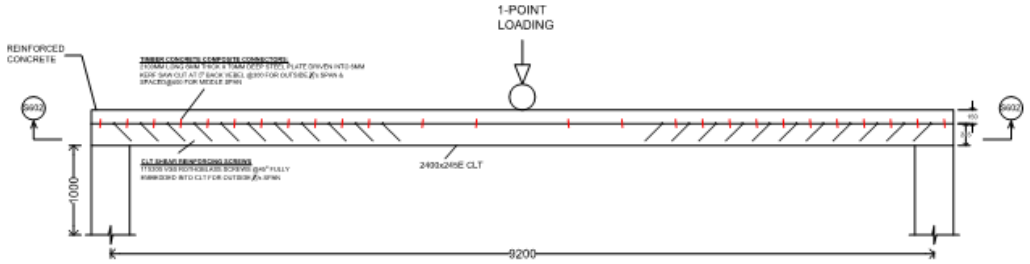
FULL SCALE TESTS



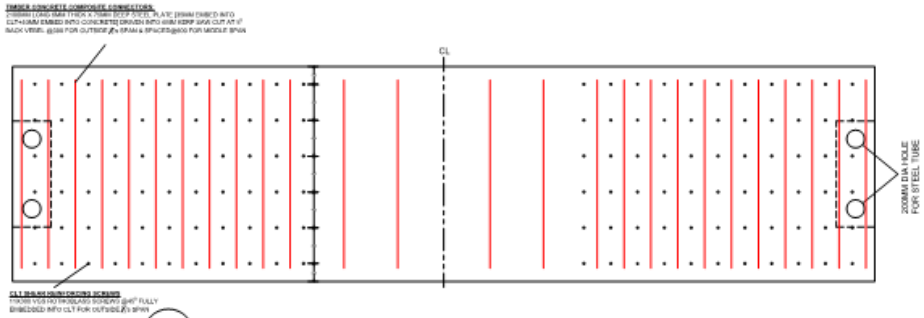
SERIES 5/6A: FULL SCALE TCC TYPE I WITH HALF-REINFORCED CLT



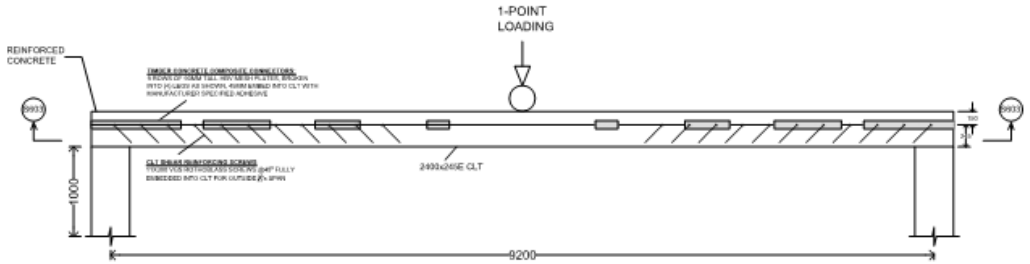
S601 PLAN VIEW OF FULL SCALE TYPE I TCC WITH HALF-REINFORCED CLT



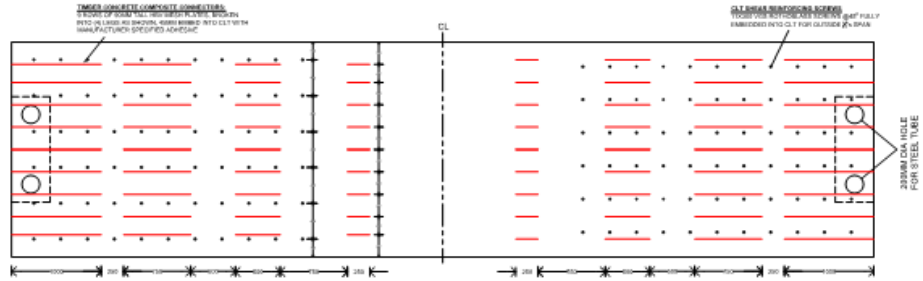
SERIES 5/6B: FULL SCALE TCC TYPE II WITH HALF-REINFORCED CLT



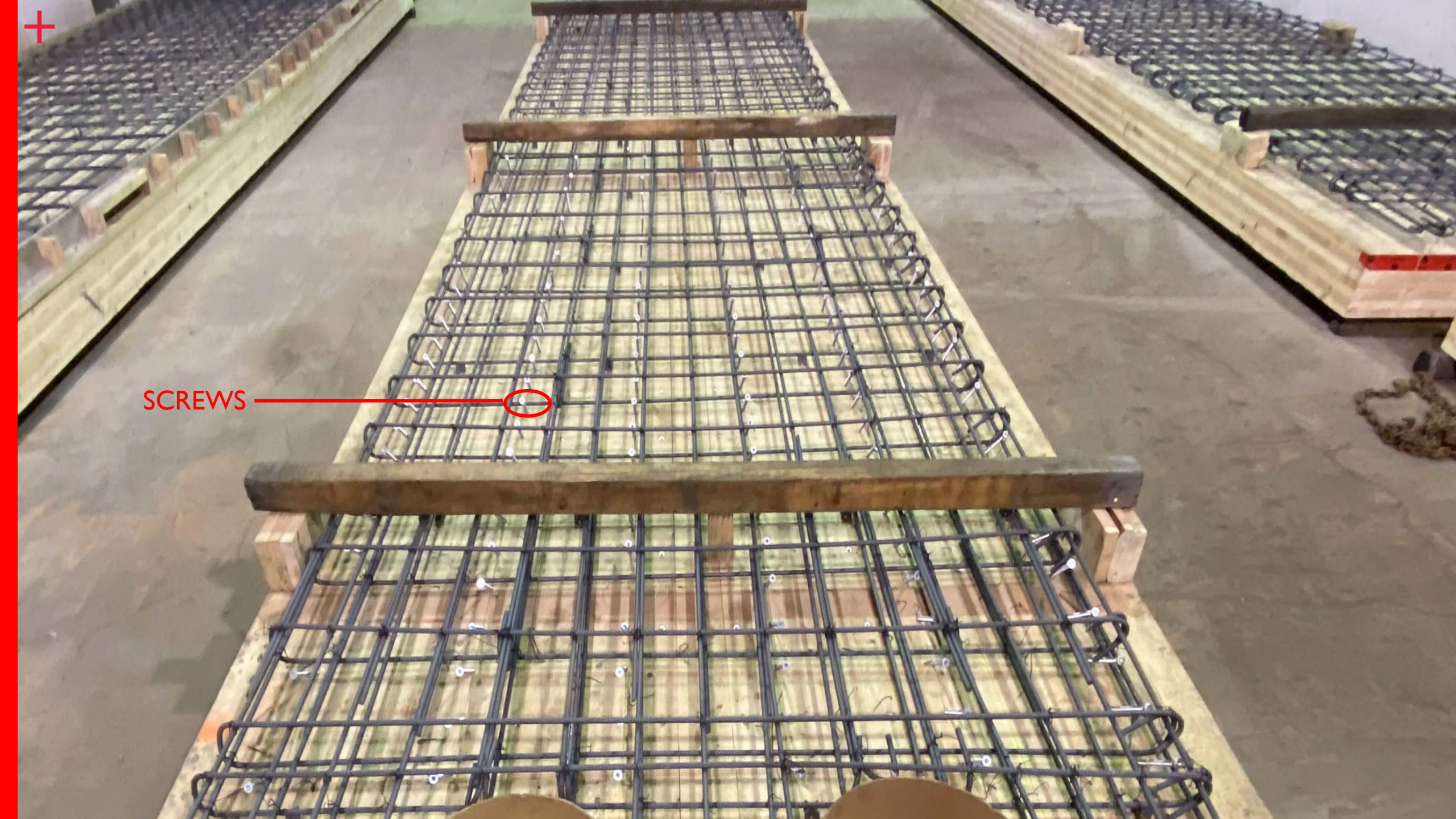
S602 PLAN VIEW OF FULL SCALE TYPE II TCC WITH HALF-REINFORCED CLT



SERIES 5/6C: FULL SCALE TCC TYPE III WITH HALF-REINFORCED CLT

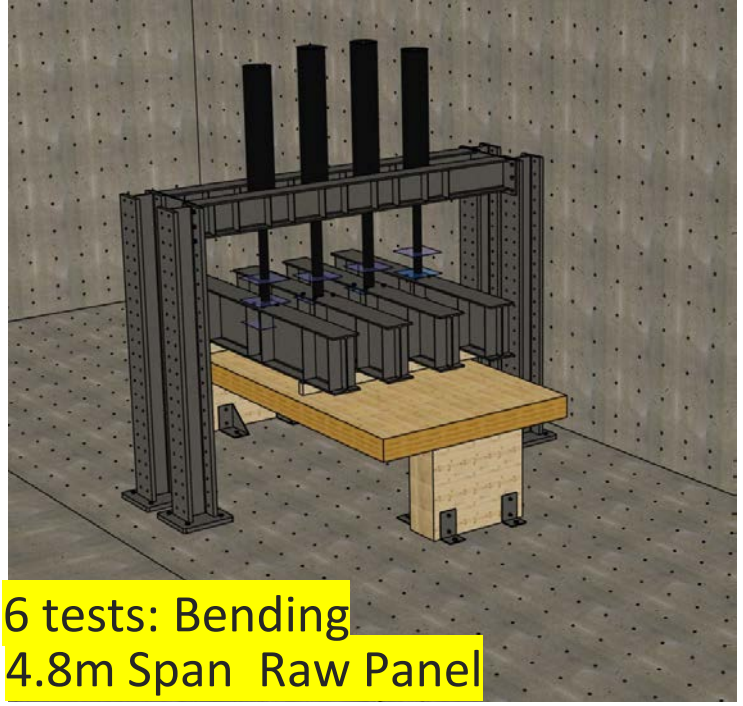


S603 PLAN VIEW OF FULL SCALE TYPE III TCC WITH HALF-REINFORCED CLT

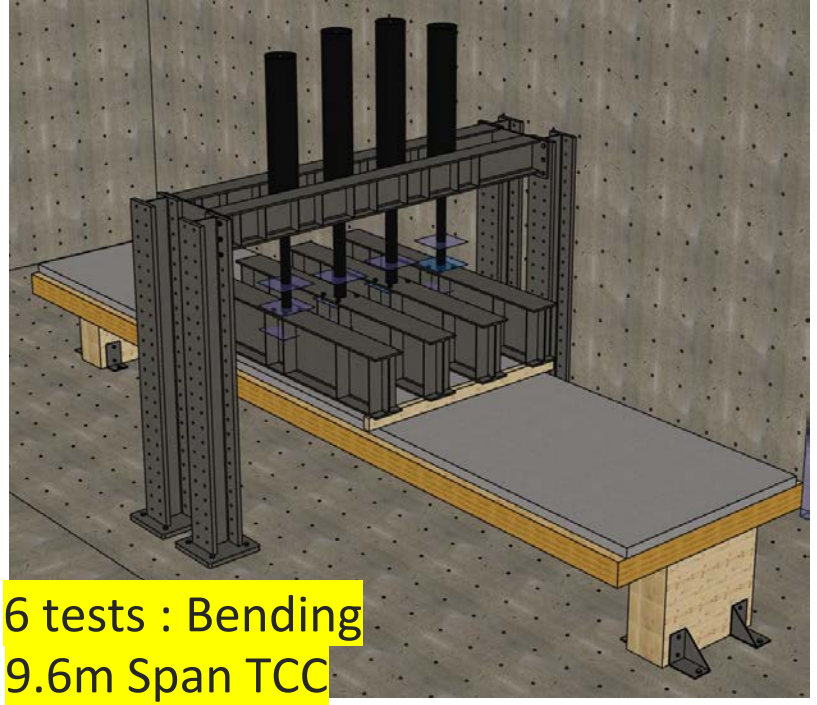

SCREWS

KERF
PLATES

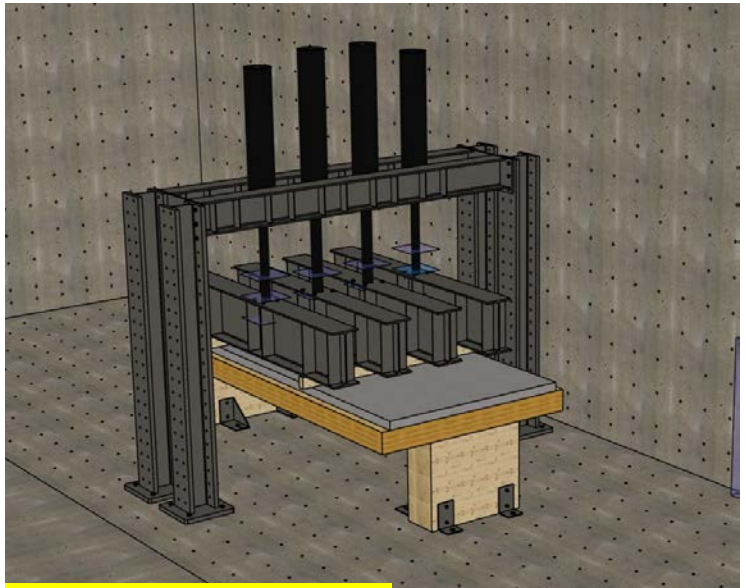
HBV



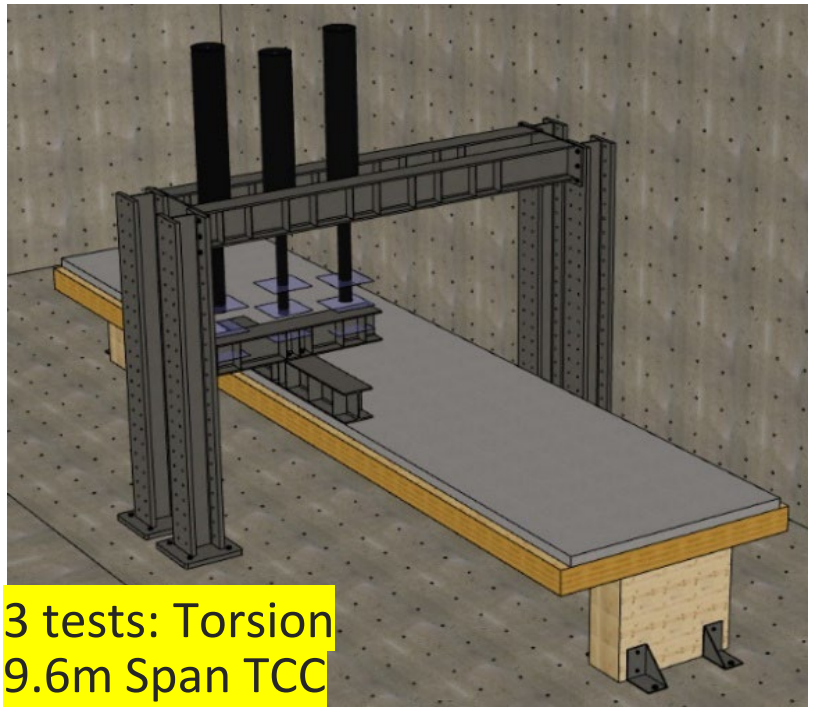
6 tests: Bending
4.8m Span Raw Panel



6 tests : Bending
9.6m Span TCC



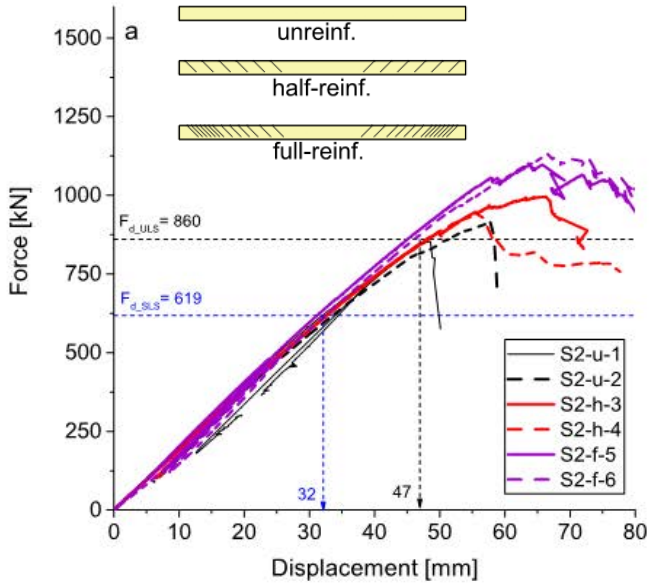
18 tests : Bending
4.8m Span TCC

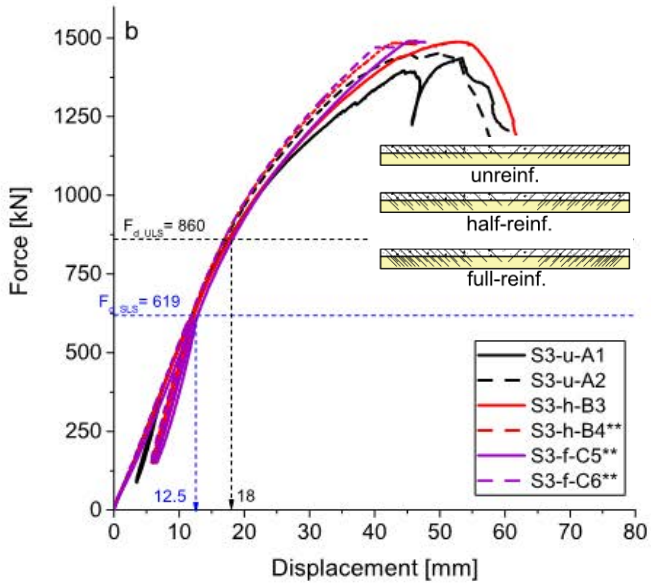


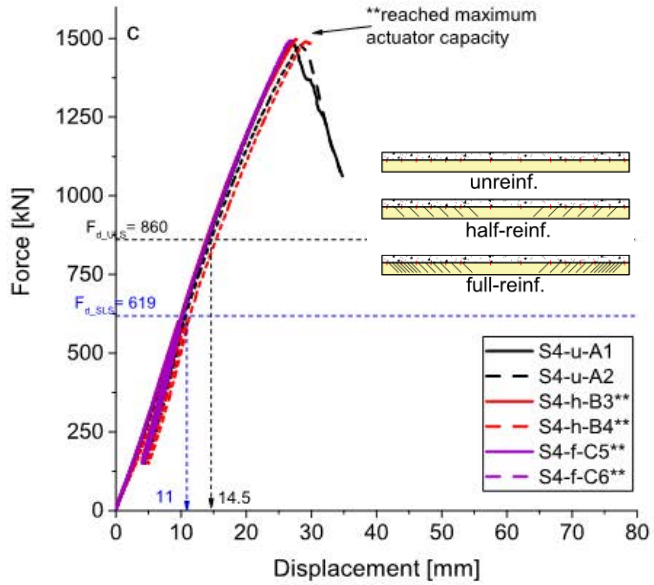
3 tests: Torsion
9.6m Span TCC

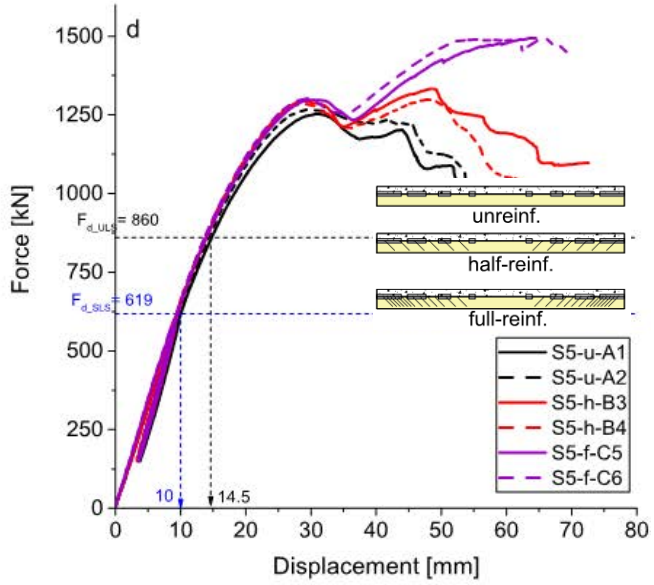
REDUCED LOAD ZONE
REDUCED LOAD ZONE
GBC-S6-B2
Atlas Copco

HALF SCALE RESULTS





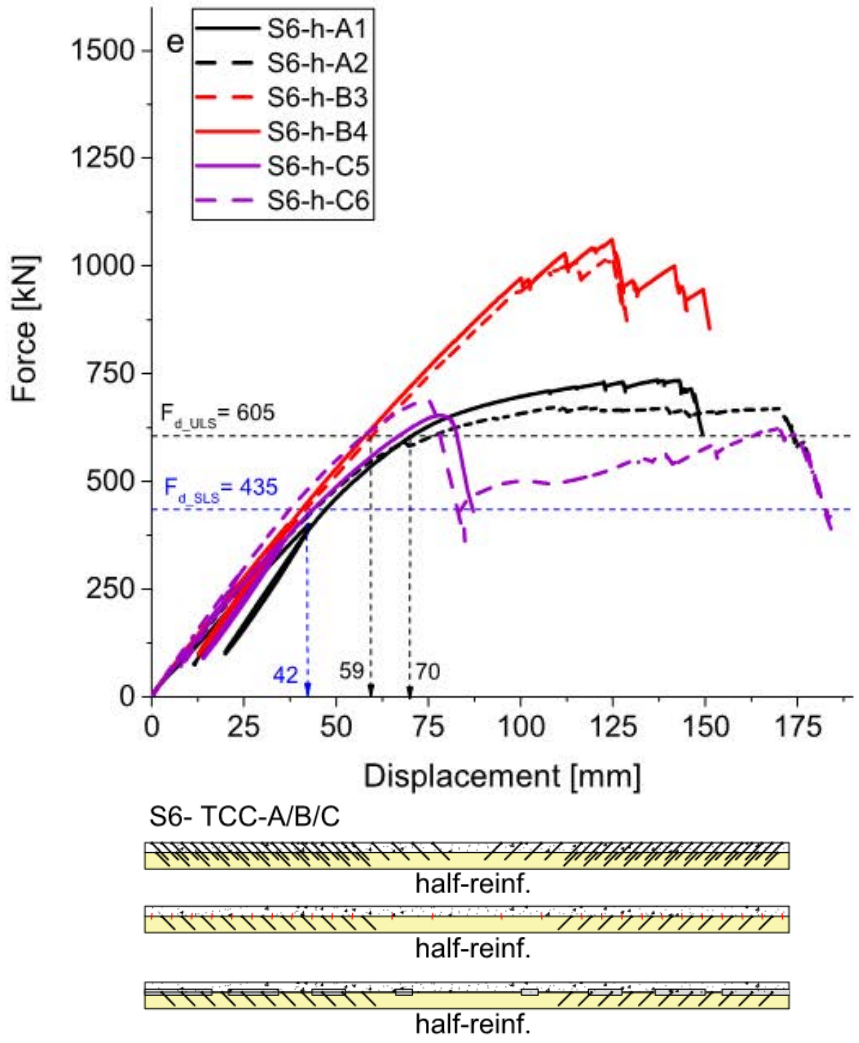


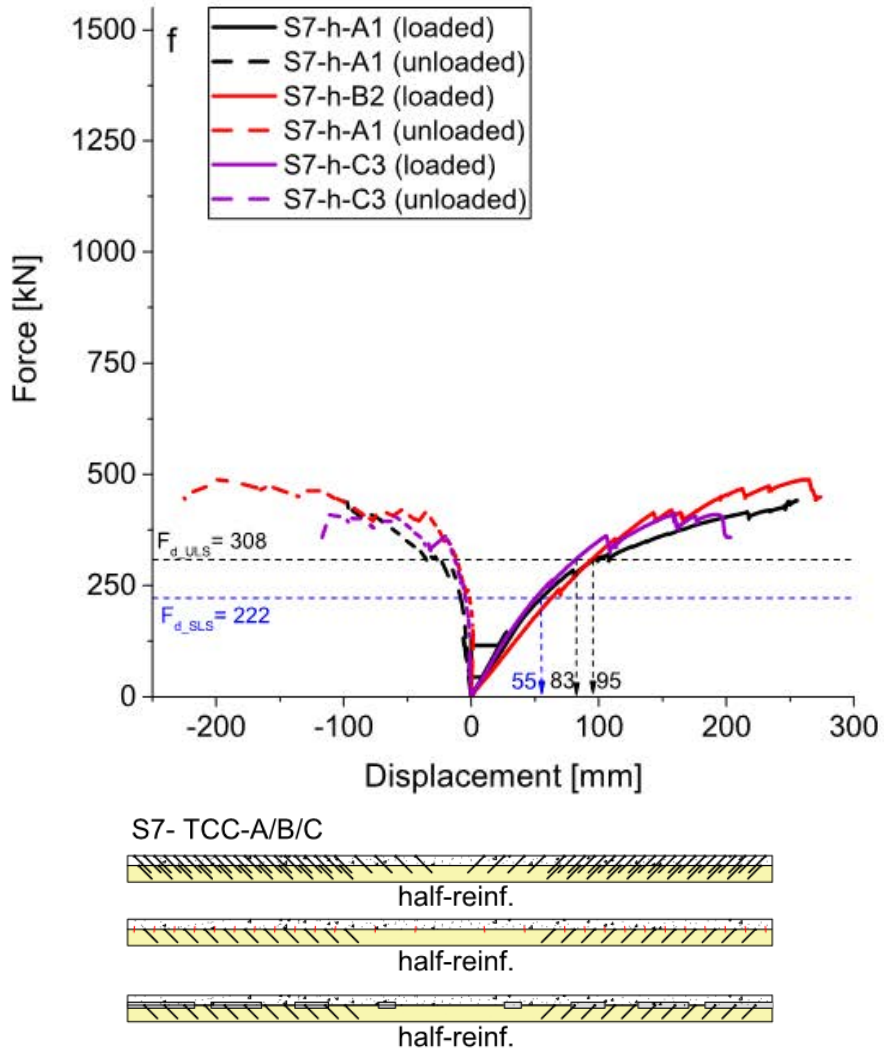


GBC-S2-A2

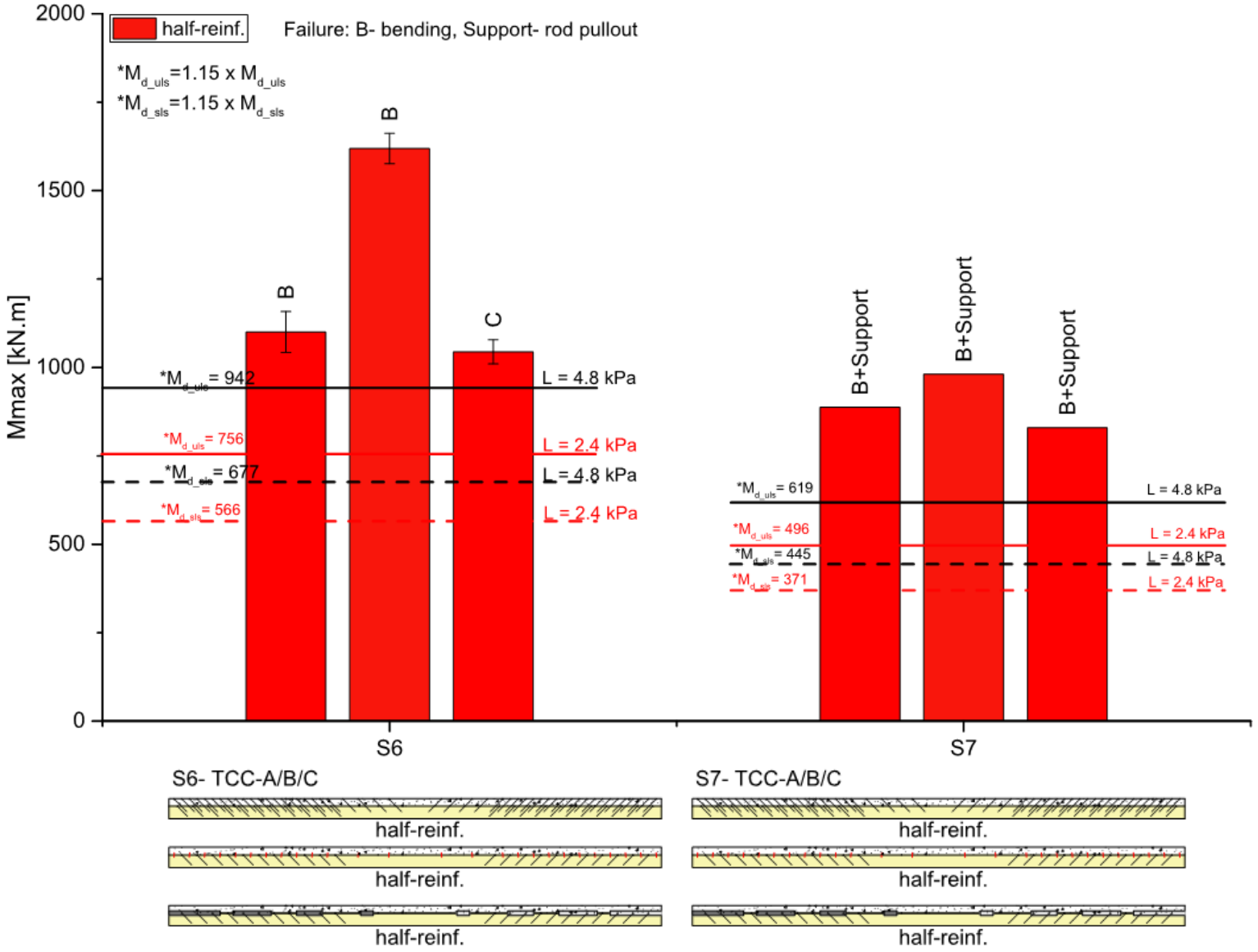
GBC-S3-B1

FULL SCALE RESULTS





FULL SCALE RESULTS



GBC-S6-A1

GBC-S6-B1

GBC-S7-A

TESTING CONCLUSIONS

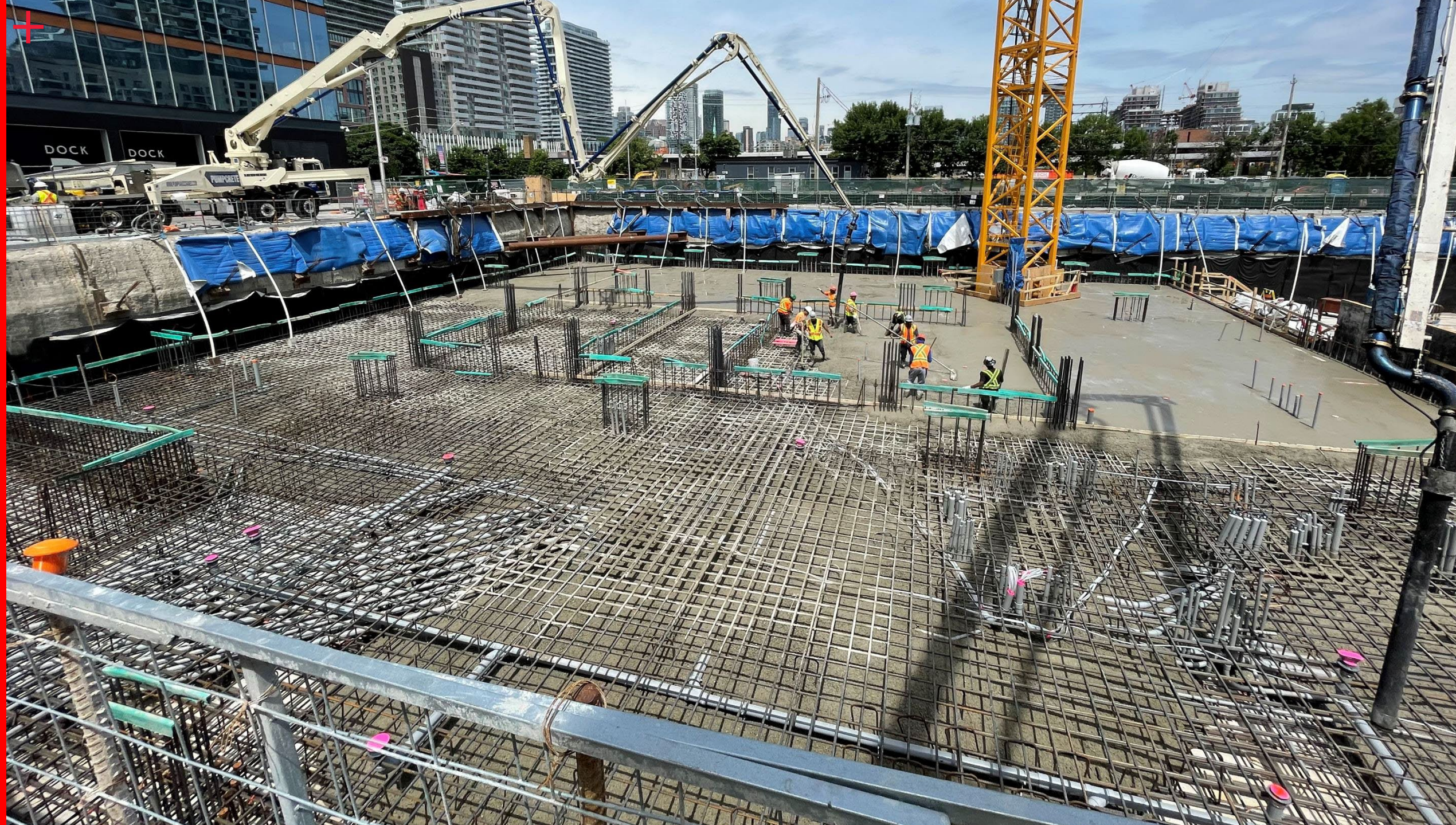
- Concrete layer increased out-of-plane shear capacity of panel significantly
- Design had sufficient capacity; some adjustments were made in weak axis.
- Kerf plates proved to be a stiff, safe, and economical solution for shear flow
- Vibration observations helped calibrate models.

AGENDA

Design

Structural Testing

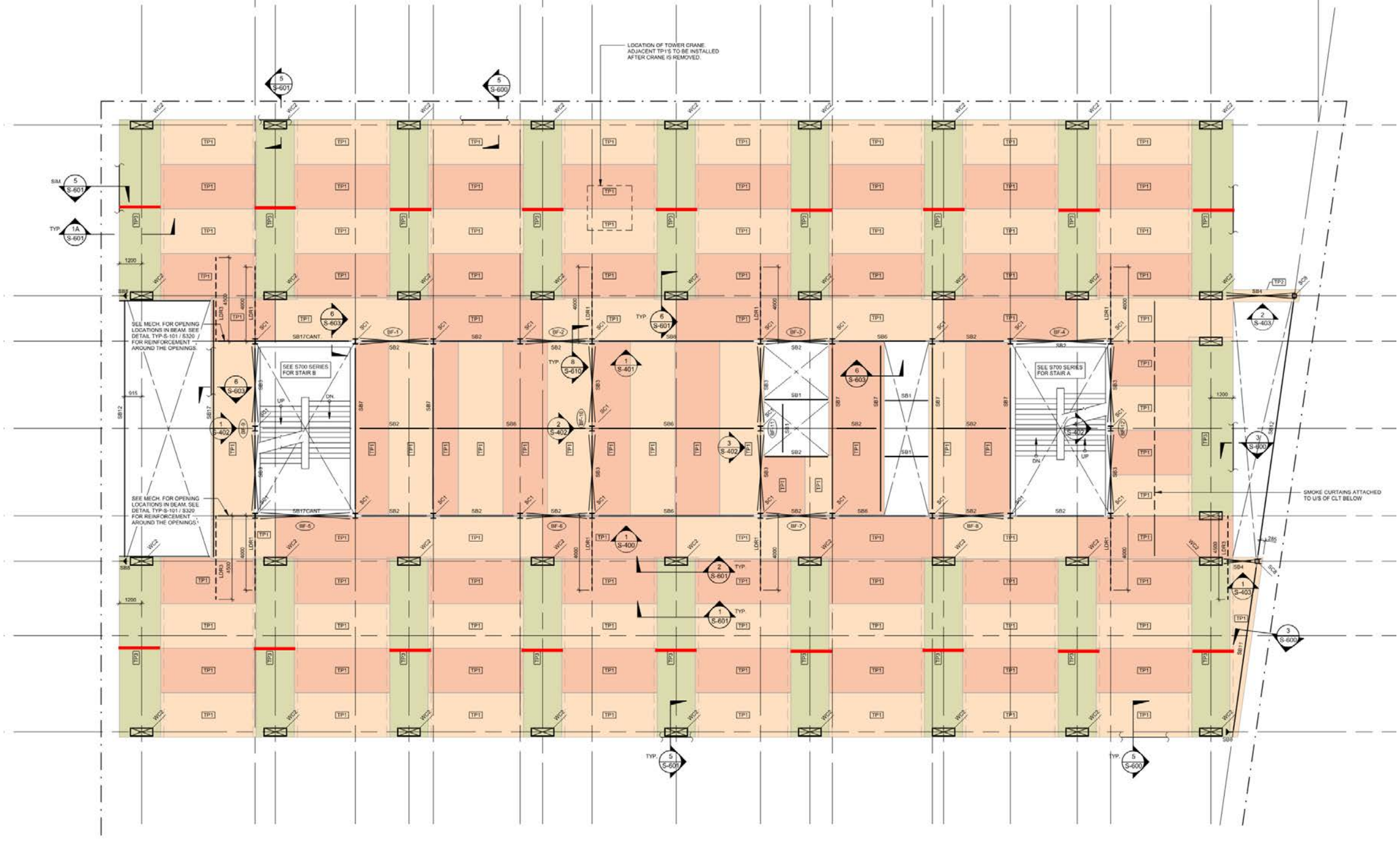
Fabrication & Construction

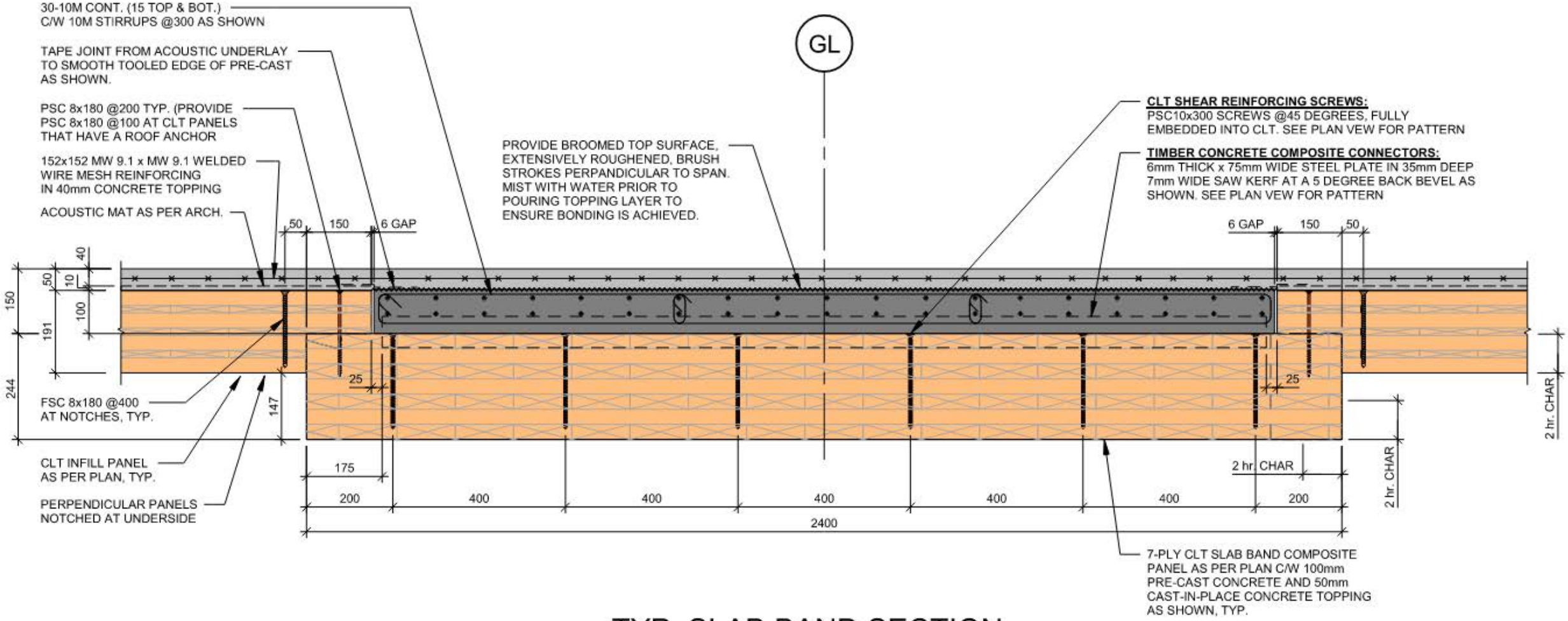

DOCK
DOCK
PUMPCRETE

27A
SORTIE

Self
Storage

mm/inch
699
OFF
ON
ZERO


LOCATION OF TOWER CRANE. ADJACENT TP1'S TO BE INSTALLED AFTER CRANE IS REMOVED.
SEE MECH. FOR OPENING LOCATIONS IN BEAM. SEE DETAIL TYP-S-101 / S320 FOR REINFORCEMENT AROUND THE OPENINGS.
SEE S700 SERIES FOR STAIR B
SEE S700 SERIES FOR STAIR A
SMOKE CURTAINS ATTACHED TO U/S OF CLT BELOW



TYP. SLAB BAND SECTION

NORDIC
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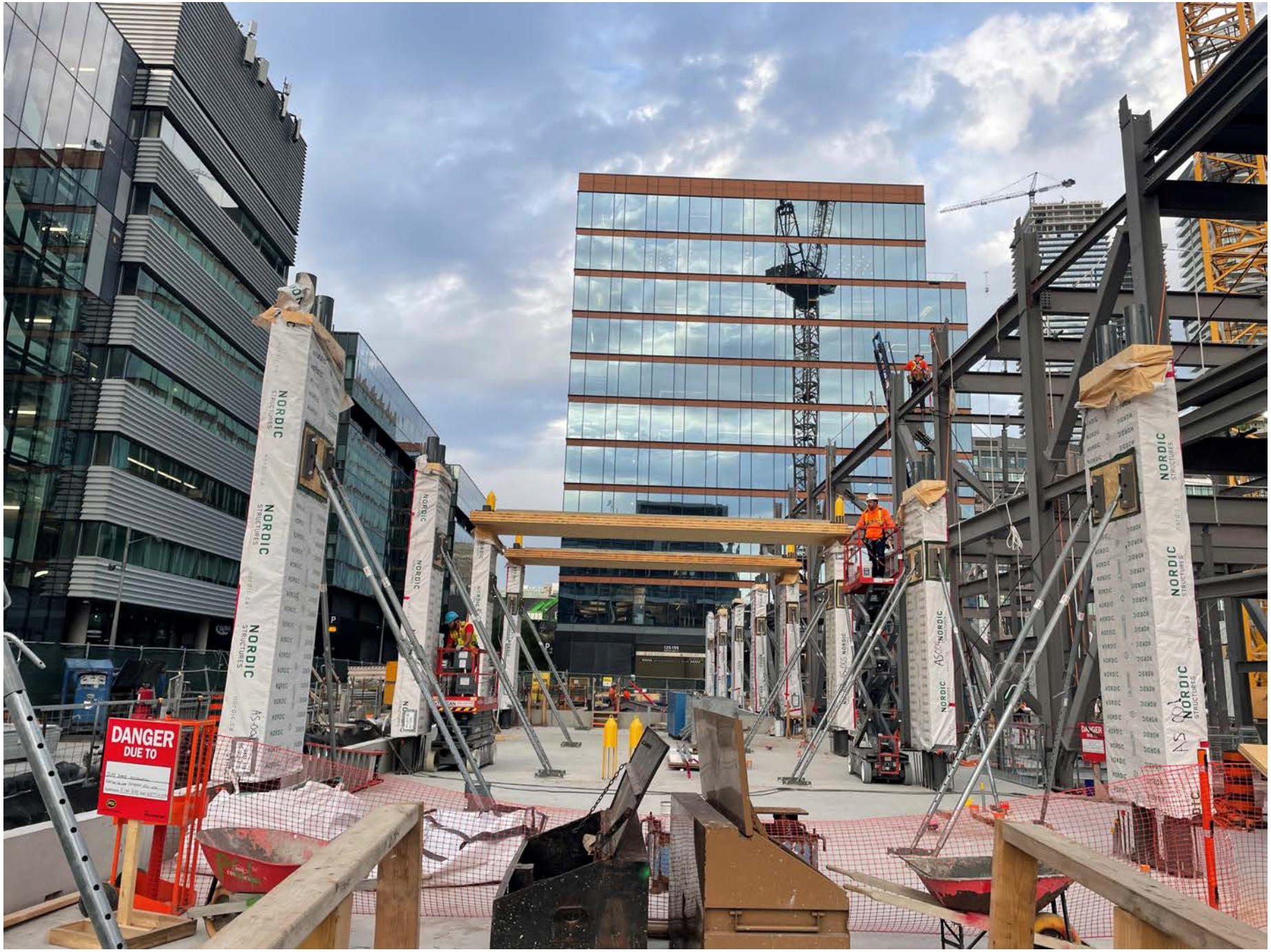
NORDIC
NORDIC
nordic.ca
STRUCTURES

CBM
MACK
CBM


NORDIC
STRUCTURES
DANGER
DUE TO

C193

K31
K33

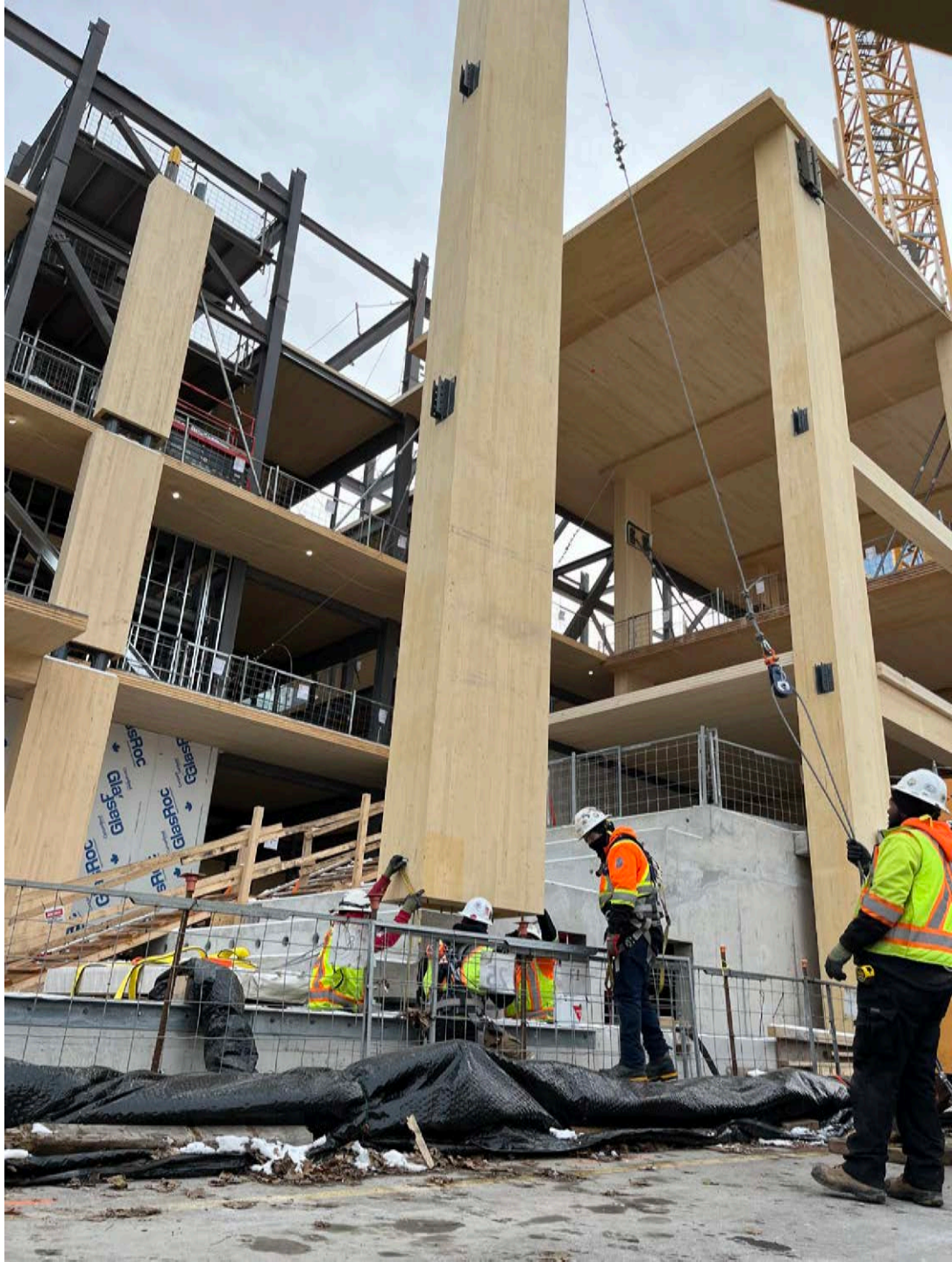
SKYJACK
SJIII 3219
NORDIC
STRUCTURES
SKYJACK

NORDIC
STRUCTURES
nordic.ca

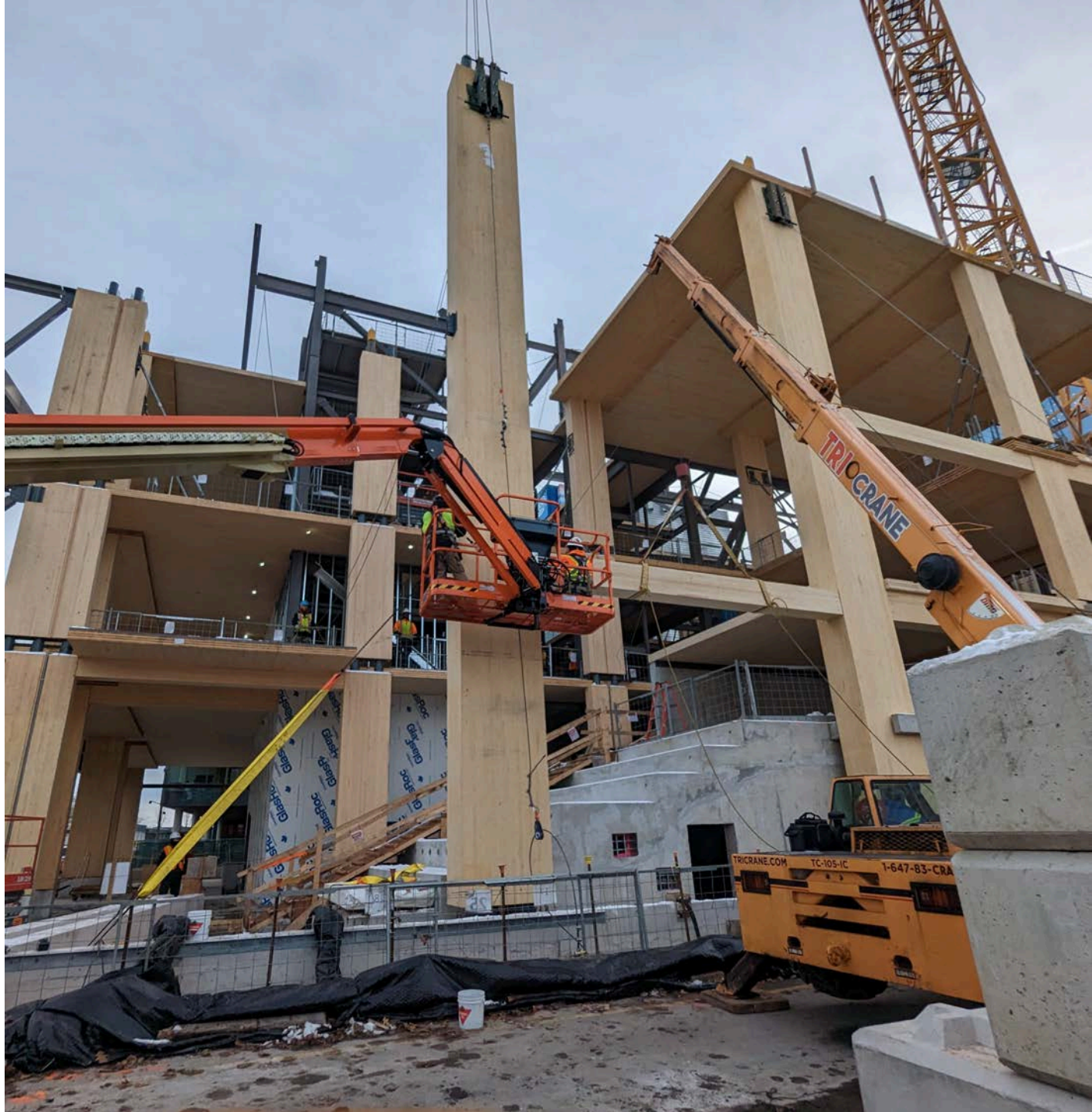
NORDIC
AS061

WEBSTOCK
MADE IN CANADA

DOCK


GlasRoc

TRICRANE.COM
TC-105-I


TRICRANE
TRICRANE.COM
TC-105-IC

DANGER

LIMBERLOST PLACE
PCL
CONSTRUCTION
DANGER
DUE TO
100% TIE OFF REQUIRED
BEYOND THIS POINT

NO STANDING
PCL

PCL
GEO

Dockside
Quay E

Thank You

Robert Jackson
Partner | P.Eng, Struct.Eng, P.E., S.E., C.Eng., MIStructE