Sample RKALC Structure

Structure in question is slender tall building with the following characteristics:

1-Office building of 27x27m² floor plate, central core of 9x9m² footprint

2-46 storeys, with total height of 150m from footings to roof.

3-Aspect ratio of the building = 5.55 (slender)

4-Wind loads onto the building estimated at average of 2.75 KPa for conceptual purposes. It is expected to have high cross wind loads

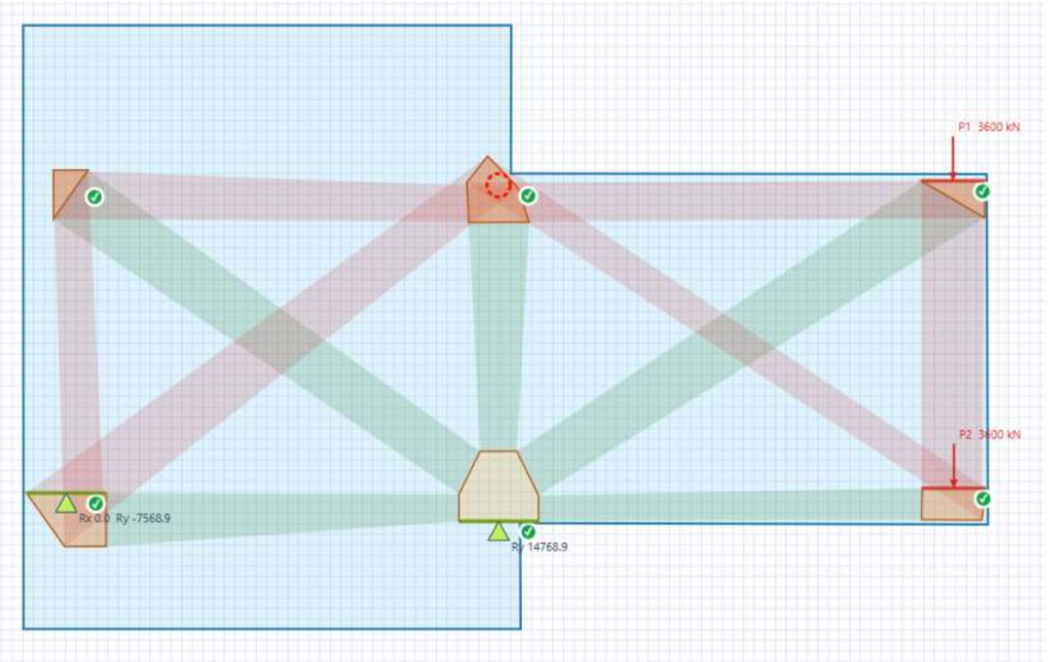
This example will discuss the overall structural building behaviour, including:

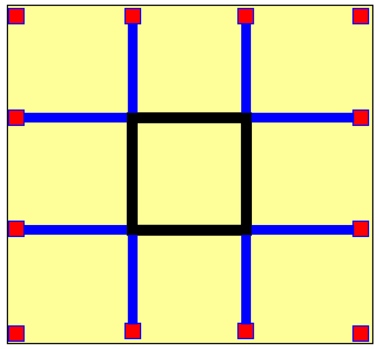
-Total overturning moments and shears

-Deformation of the building with and without outrigger, and justification for the necessity of outrigger supported lateral system

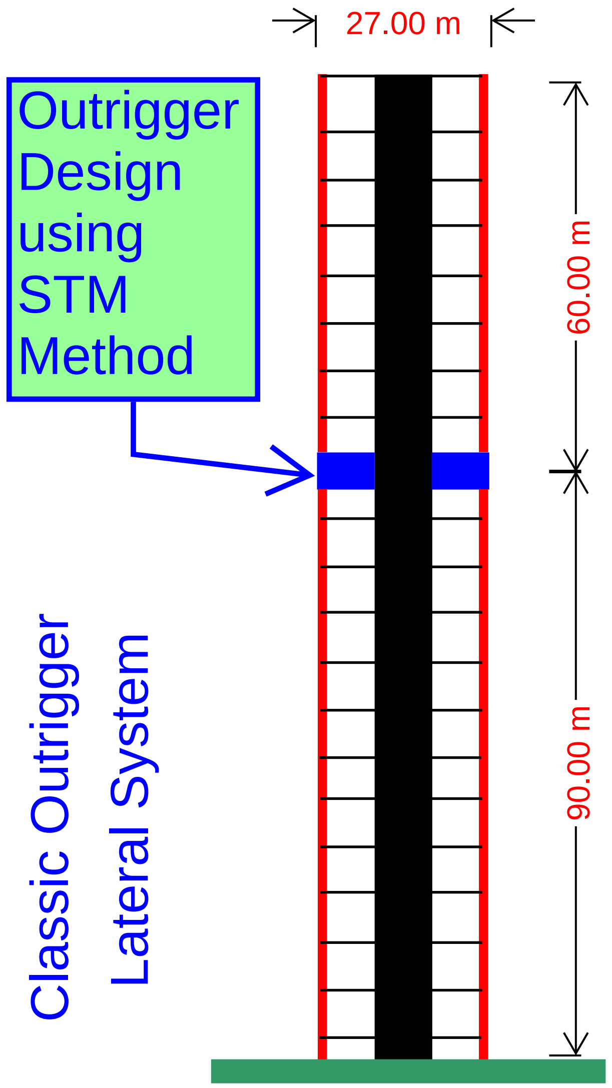
-Finding the load path within the core and outrigger

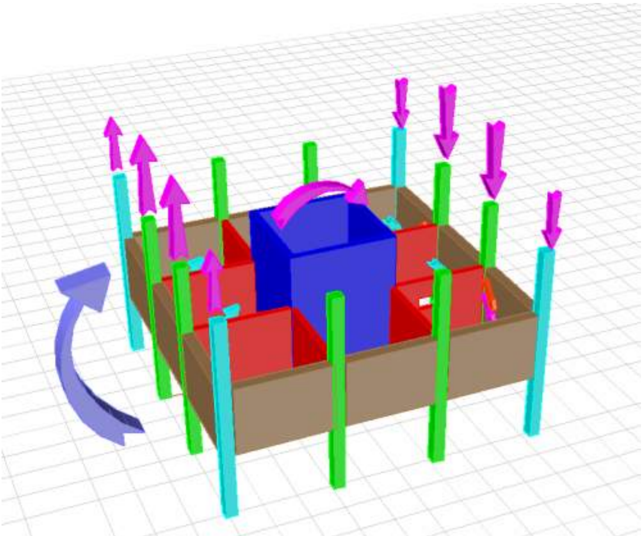
-Designing the outrigger wall using RKALC STM Studio

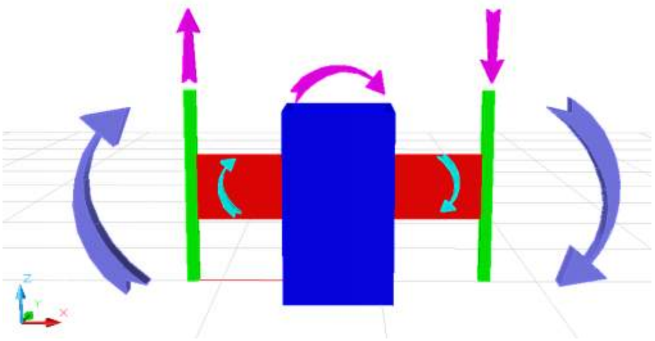




27x27 m²
Floor Plate
150 m Tall
(5.55 Aspect ratio)







Description of Building

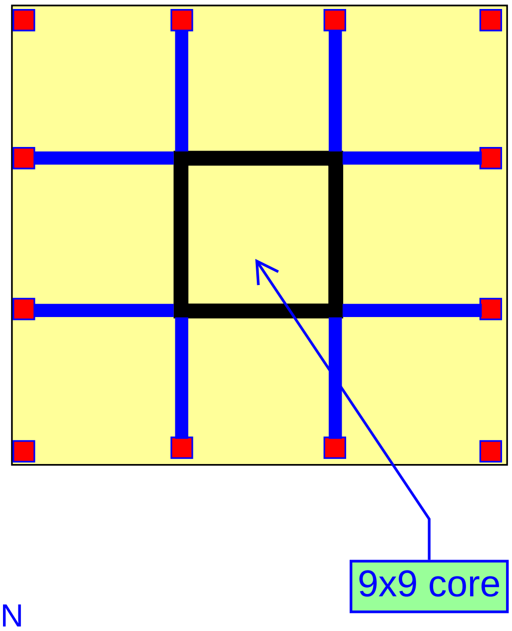
A- Gravity System and loads

This is an office building with typical loads as follows

1- Loads : SDL = 2 KPa and

LL = 3 KPa

2- Slab system is PT with thickness = 240 mm (6KPa)



Therefore

ULS = (2+6) * 1.2 + 3 * 1.5 = 14.1 KPa

SLS = 2 + 6 + 3 = 11 KPa

average storey mass = 27x27x11 * 1.25 = 1000,000 kg

Typical Column Size

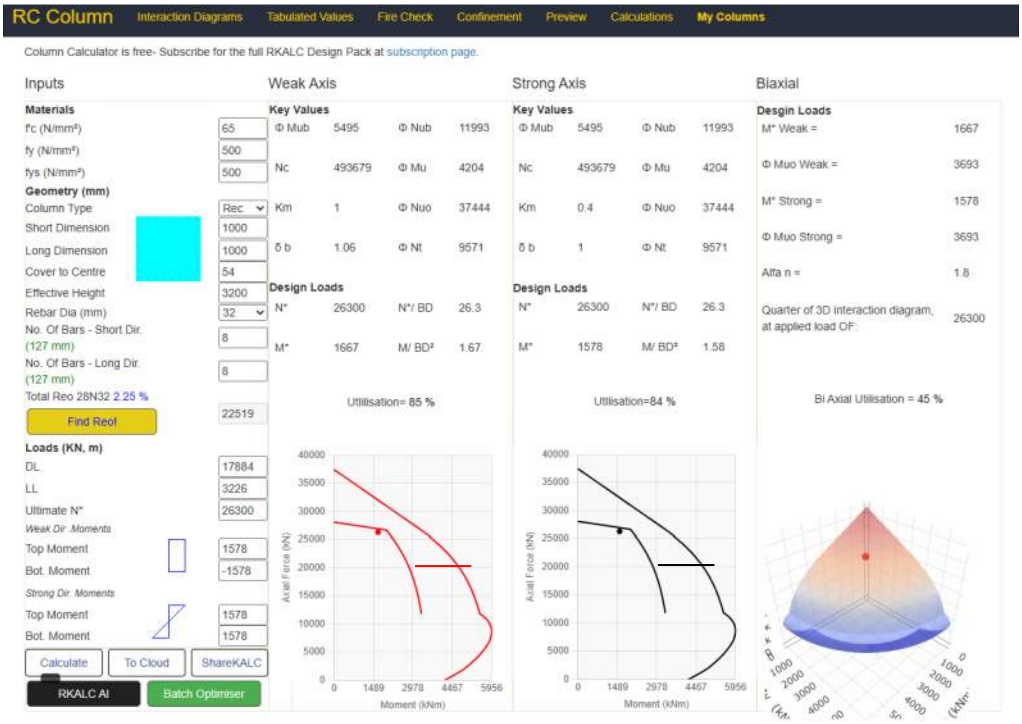
Typical column loads are at 9x4.5 x 14.1 x 46 = 26,300 KN

and this means typical column size is

Width = SQRT (26300 * 1000 / 65MPa / 0.40) = 1006x1006

Adopted column size = 1200 x 1200 mm²

(Note size is derived by loading columns to say 0.75 of squash load)



B - Lateral System

Building is very slender and will ultimately require wind tunnel testing, in this example we are either peer reviewing the building or putting an initial scheme of things. therefore will estimate the lateral loads.

The building is fundamentally having bendy behaviour, slender with such aspect ratio (5.55), and therefore the most likely governing lateral load will be wind (building of high period or roughly 6 to 7 seconds (approx period = number of storeys / 10 or height / 44 and a bit more)

For benchmarking wind loads:

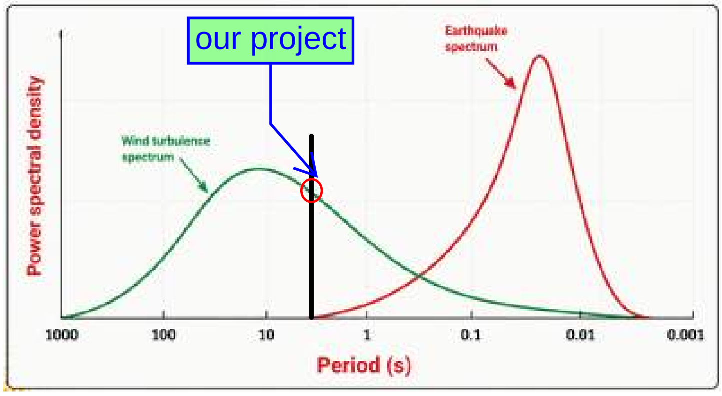
2.75KPa average wind pressure gives the following base reactions

Pressure = 2.75 KPa

Equivalent Line load = 2.75 * 27 = 75 KN/m

Base moment = 75 * 150^2 / 2 =

say 0.900 GN.m

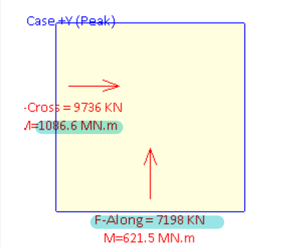


However, we can use RKALC's WindKALC to estimate wind loads more accurately, by inserting geometry (dimensions and storey mass, see below), this gives a cross wind overturning moment of 1.06 GN.m (close enough) at 1000 return period for ULS purpose

AS1170.2-2021

Criteria	
Region	A
Return Period	1/1000
Terrain Category	TC3
s(m)	153.6
Storey Height (m)	3.2
No. of Storeys	48
Total Height H (m)	153.6
Bldg. X Dimension (m)	27
Bldg. Y Dimension	27
Site Wind Speed Vr	46
Damping	0.03
Average Storey Mass (kg)	1000000
M z,cat (H)	1.2124
Along-Cross Combo Factor α	0.80

Case +Y | -Y | +X | -X



Directional Inputs

Insert the values for each direction based on building geometry, wind cardinal directions and dynamic properties from analysis model:

Along Y Direction	
Building Period (sec)	6
CPe Windward	0.8
CPe Leeward	0.5
Combination Factor Kc	0.9
Md Dir Factor +Y	0.9
Md Dir Factor -Y	0.8
Ms Shielding Factor +Y	1
Ms Shielding Factor -Y	0.95
Building Aspect Ratio (h:b:d) facing load	6:1:1

Along X Direction	
Building Period (sec)	6
CPe Windward	0.8
CPe Leeward	0.5
Combination Factor Kc	0.9
Md Dir Factor +X	1
Md Dir Factor -X	0.85
Ms Shielding Factor +X	0.8
Ms Shielding Factor -X	1
Building Aspect Ratio (h:d:b) perp direction	6:1:1

Dynamic Factor

Peak Factor gv			3.4
Turbulence Factor Ih			0.1491
Lh	168	Hs	2

Y Direction Calcs	+Y	-Y
Size Red. Fctr. S	0.176	0.146
N	0.842	0.997
Et	0.1	0.089
Gust Factor	2.42	2.32
Dyn Fctr Cdyn	1.2	1.15
Peak Factor gR	3.227	
Bacground Factor Bs	0.902	

X Direction Calcs	+X	-X
Size Red. Fctr. S	0.154	0.165
N	0.947	0.892
Et	0.092	0.096
Gust Factor	2.34	2.38
Dyn Fctr Cdyn	1.164	1.182
Peak Factor gR	3.227	
Bacground Factor Bs	0.902	

Update | Diagrams

Wind Response

Y Direction	+Y	-Y
Total Base Shear	7198	4917
Overturning Moment	621485	424592
Resonant Moment	221227	131861
Crosswind Base Shear	9736	4831
Crosswind Overturning M	1086602	539394
Reduced Wind Speed	7.4	6.25
Log10(Cfs)	-1.58	-1.9
Mode Pwr. Exponent k	1.5	1.5
Mode Shape Correction Km	1.12	1.12
Along Wind Acceleration	9.18	5.47
Crosswind Acceleration	52.57	26.1
Combined Acceleration	56.69	28.59

X Diection	+X	-X
Total Base Shear	5516	6322
Overturning Moment	476160	545917
Resonant Moment	153043	184614
Crosswind Base Shear	5979	7696
Crosswind Overturning M	667443	858829
Reduced Wind Speed	6.58	6.99
Log10(Cfs)	-1.8	-1.69
Mode Pwr. Exponent k	1.5	1.5
Mode Shape Correction Km	1.12	1.12
Along Wind Acceleration	6.35	7.66
Crosswind Acceleration	32.29	41.55
Combined Acceleration	35.17	45

Core size:

Good rules of thumb:

1- For building like this one, footprint of the core should be more than 15% of floor plate, here the core is at circa 10%, so clearly needs big thickness.

2- thickness of walls is roughly = number of levels * 10 = 500 - 600 mm.

so if the core is 9 x 9 and thickness = 600mm, inertia of core =

(9^ 4 - 7.8^4) / 12 = 238 m ^4

-Deflection at top = W * H^ 4 / (8EI) = 75 * 150^4 / (8 * 32.8E6 * 238) = 608 mm

-Assume Cracked section = 0.6 * full section, effective interia becomes = 0.6 * I - deflection becomes 608 / 0.6 = 1013

-Deflection ratio = 150 000 / 1013 = H/150 at ULS state

-for Service, deflection roughly becomes 0.65 of ULS, and also effective section is say 0.8 therefore deformation at tip = (608mm * 0.65) / 0.8 = 494 ~ H/300

Both are not acceptable metrics, would always target H/ 400 as total SLS building drift.

deflection therefore should be 150 000 / 400 = ~ 375 mm in ULS

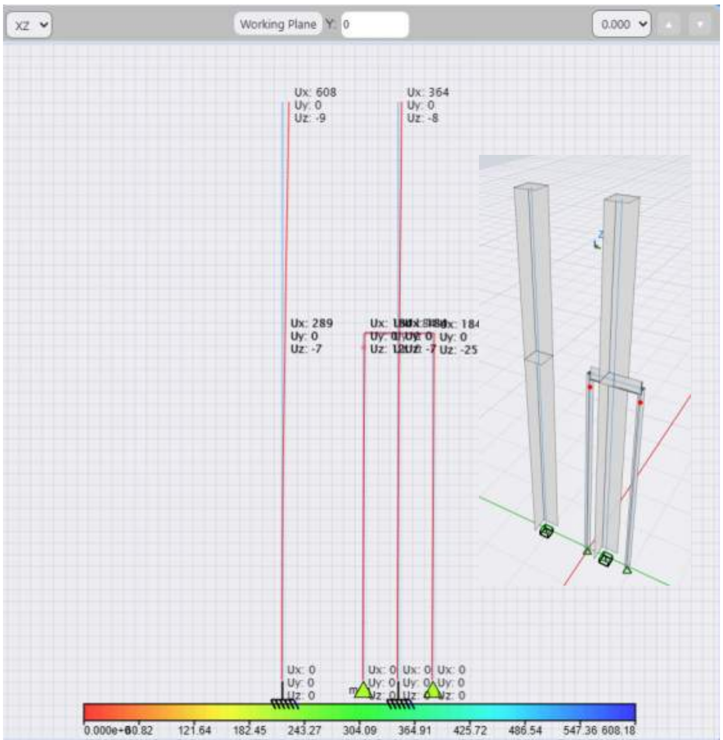
THEREFORE MUST HAVE OUTRIGGER!

will locate the outrigger at 60 meters from top and nominate height of 6.6 meters (roughly 2 levels) and thickness = 600, (this reduces the deflection to almost 50% of original.

Good rules of thumb:

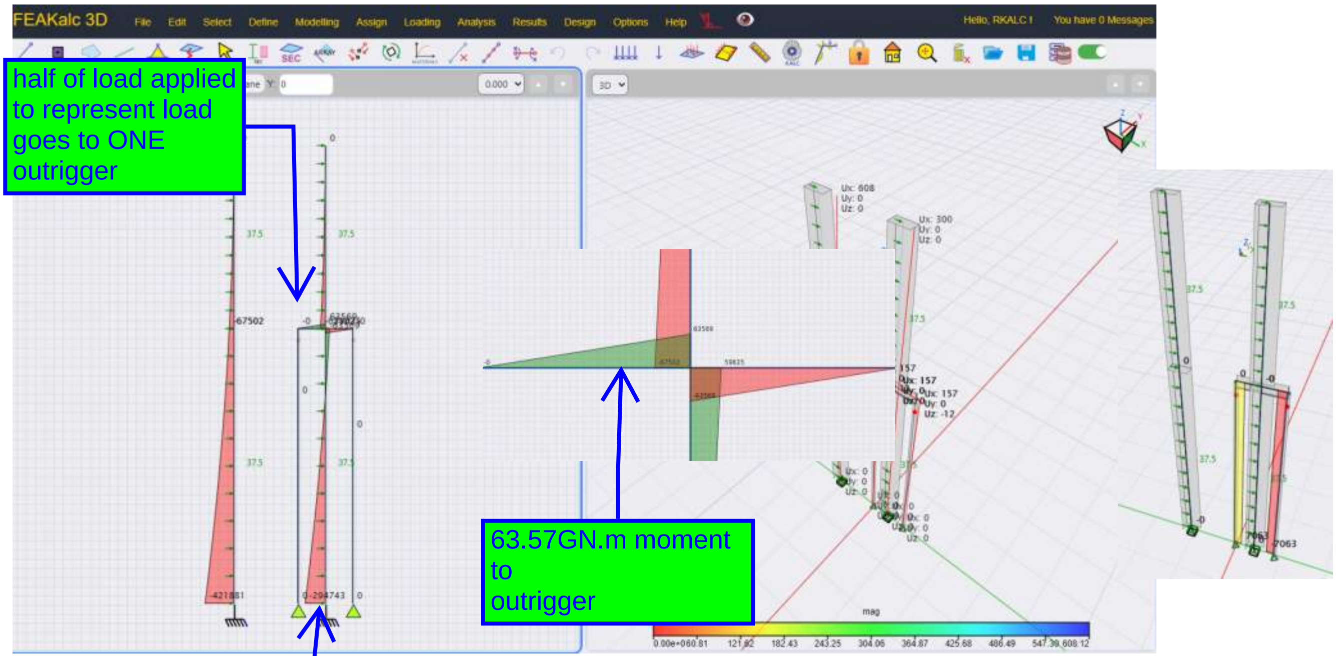
1-outrigger is ideally located at 55% of height for maximum efficiency

2- effectiveness of outrigger is dependent on 2 factors, axial area of columns connecting to it and inertia of outrigger, the more these 2 the more moment can be transmitted outside of the core.



LEARNING CENTRE	Outrigger Wall Design	By	RK
	STM Studio Worked Example	Sheet No. 5	Date 8/26

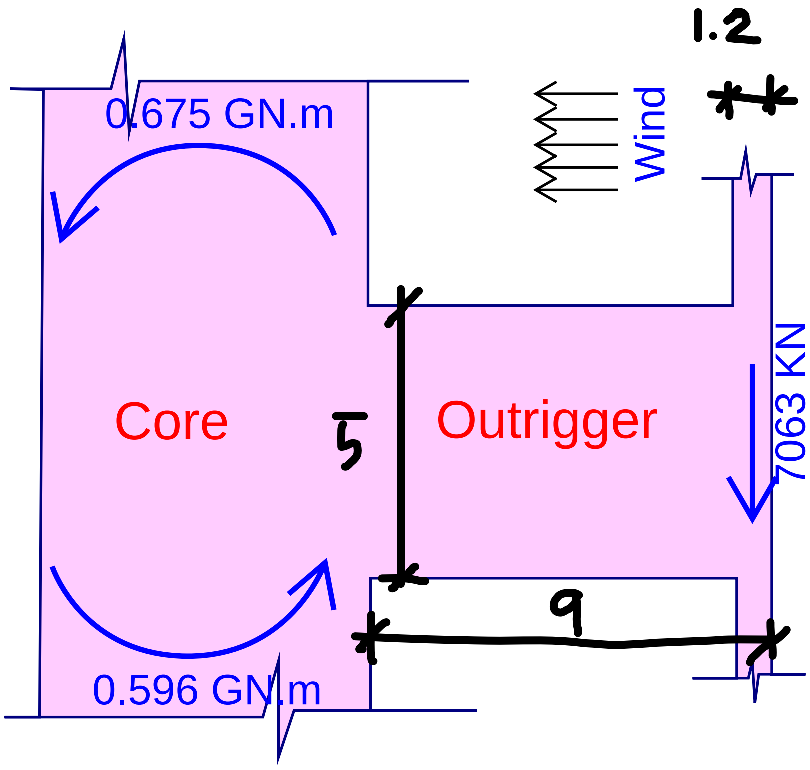
half of load applied to represent load goes to ONE outrigger

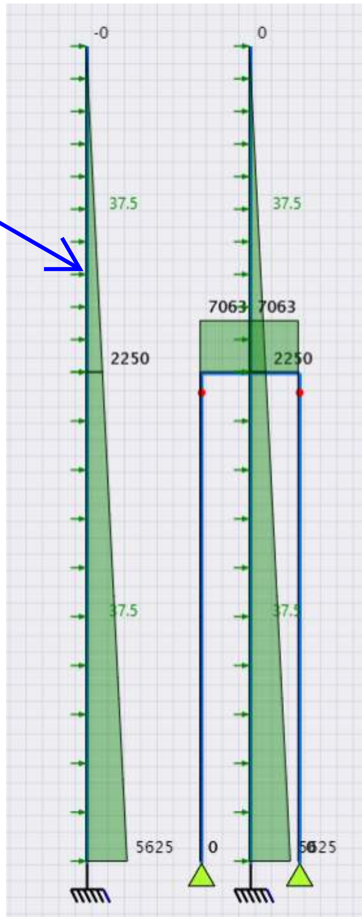


63.57GN.m moment to outrigger

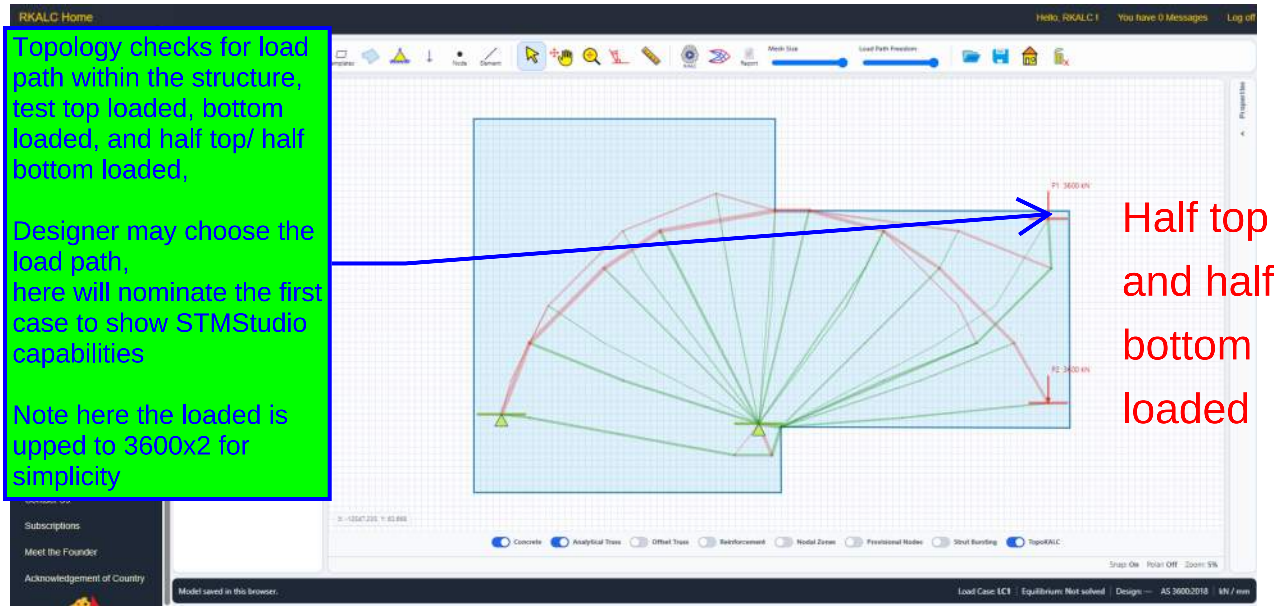
30% reduction in moment to core

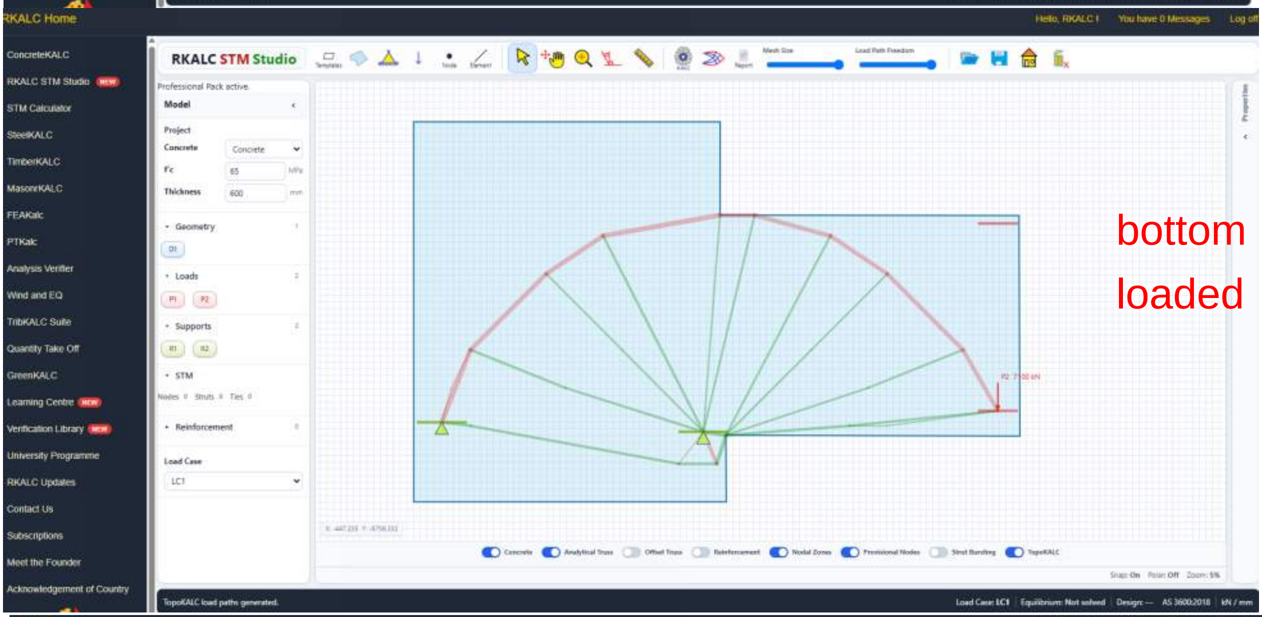
Shear to outrigger is circa 2.37 MPa which is not too high, about right

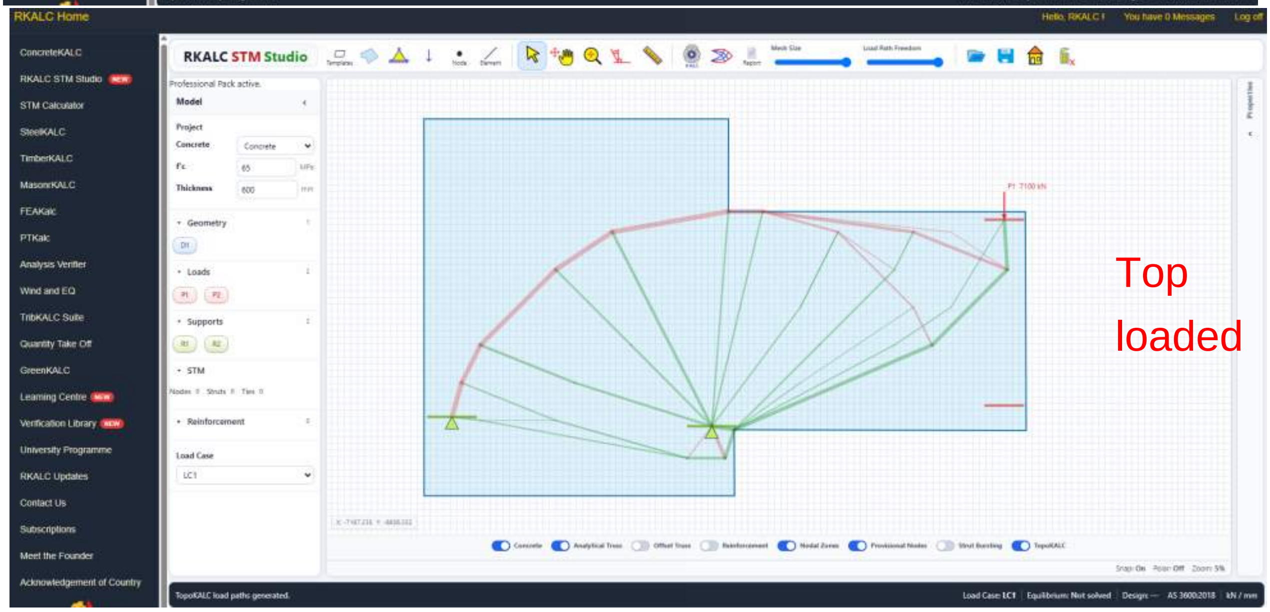




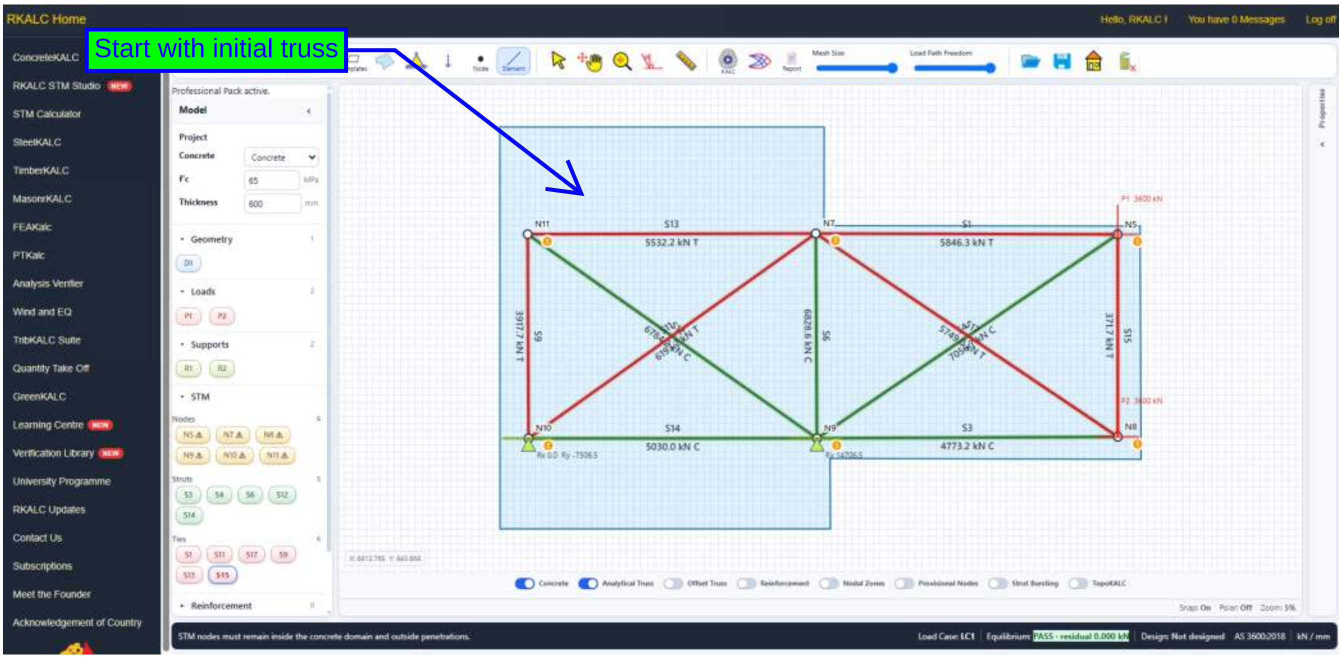
Step 1 - Load Path Finding using Topology Optimisation



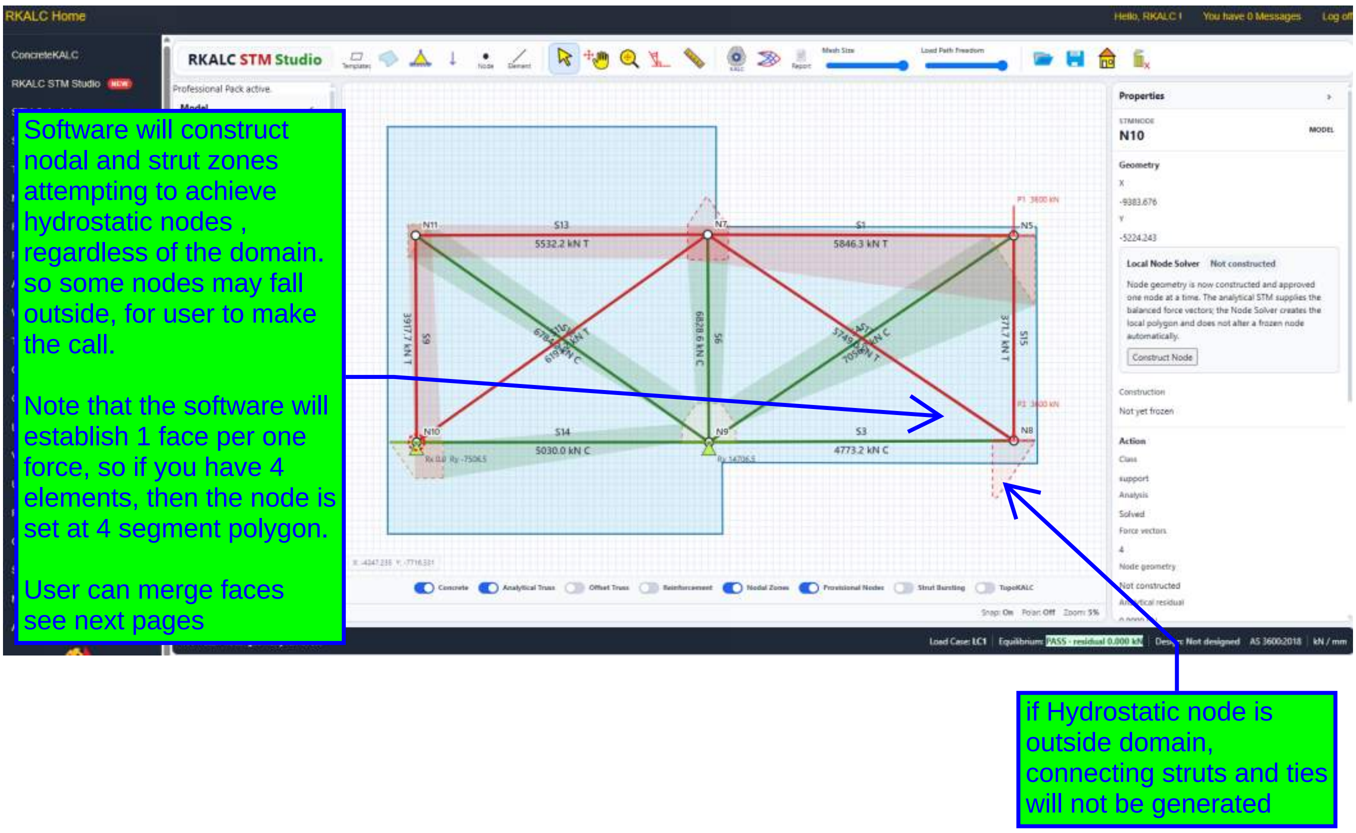




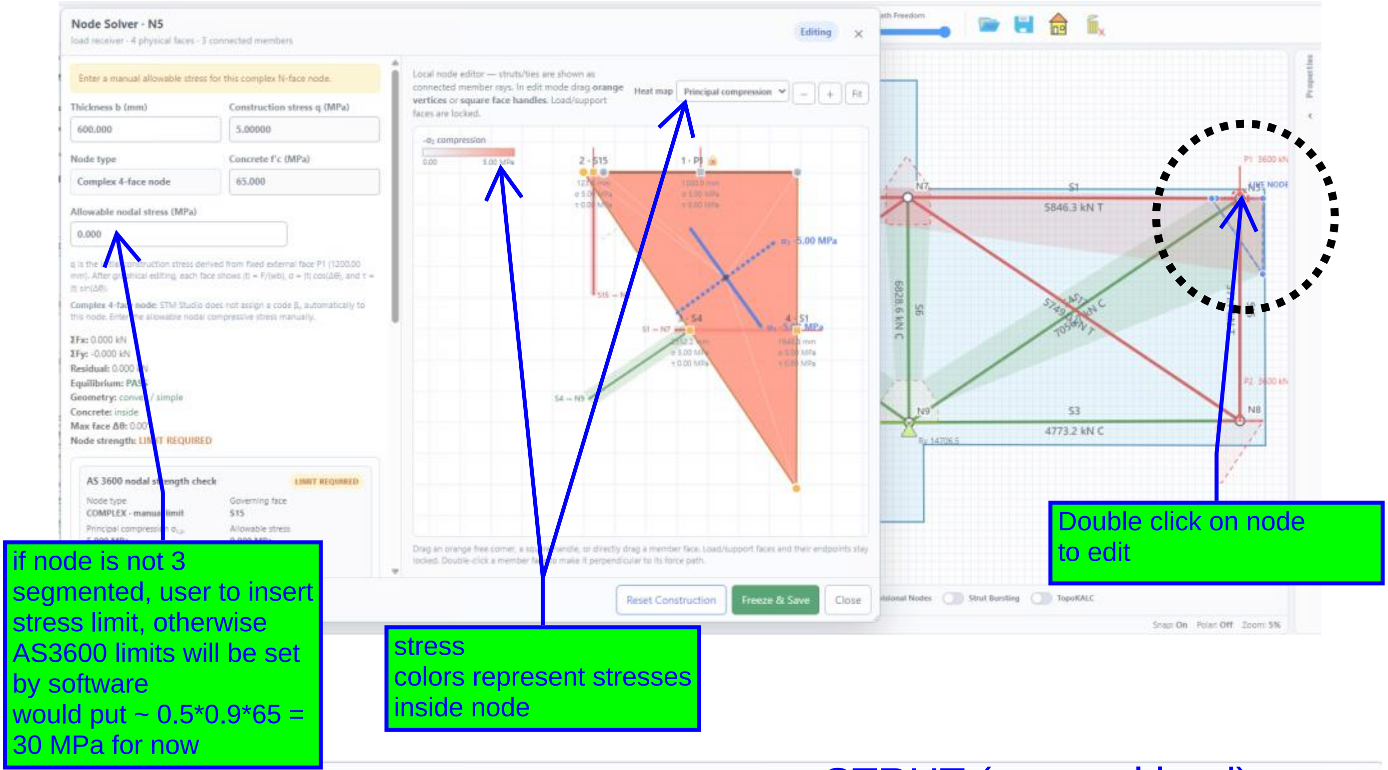
Step 2 - Constructing the Initial Strut and Tie Model

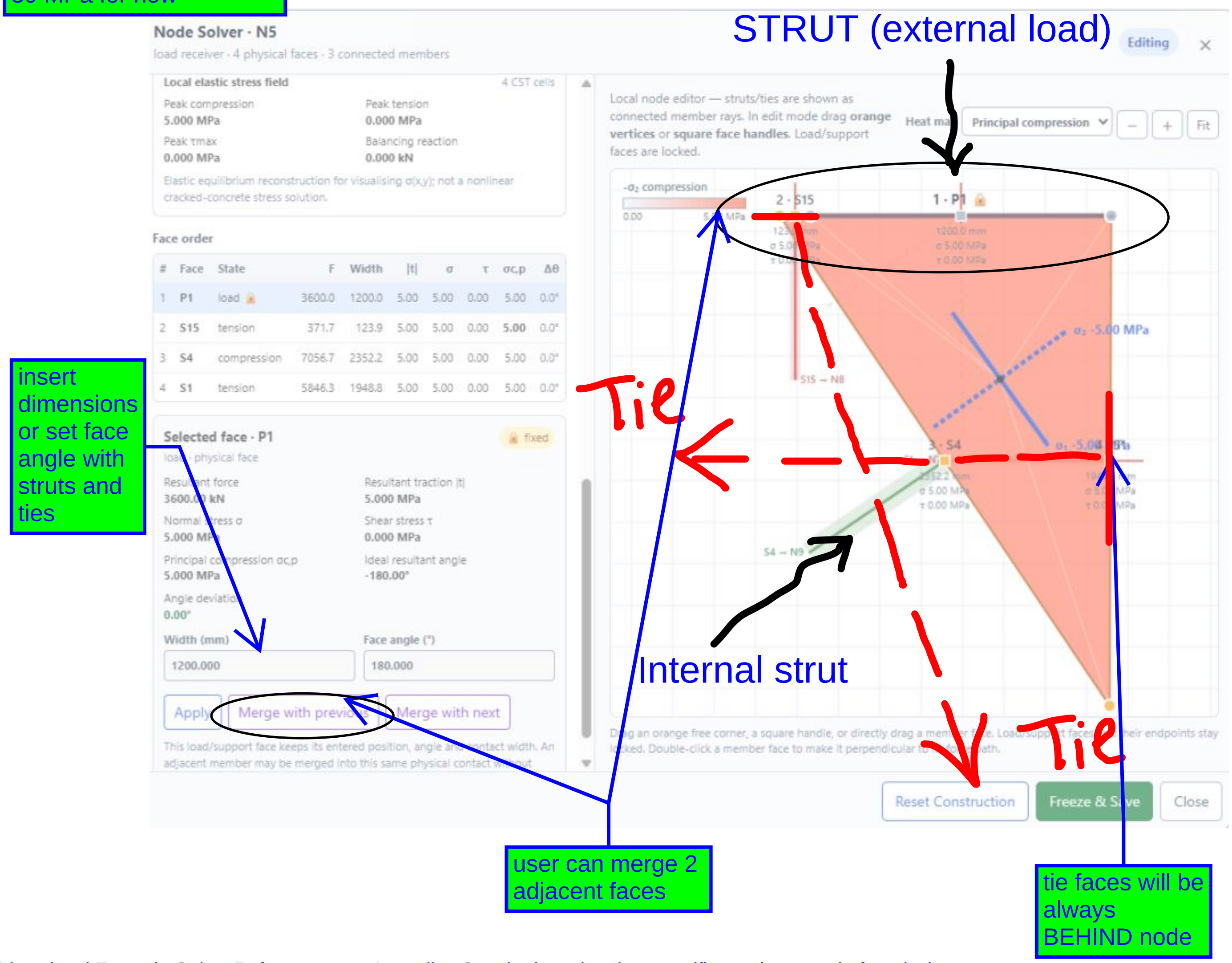


Step 3 - Reviewing Provisional Nodal Zones - Auto Node by STM Studio

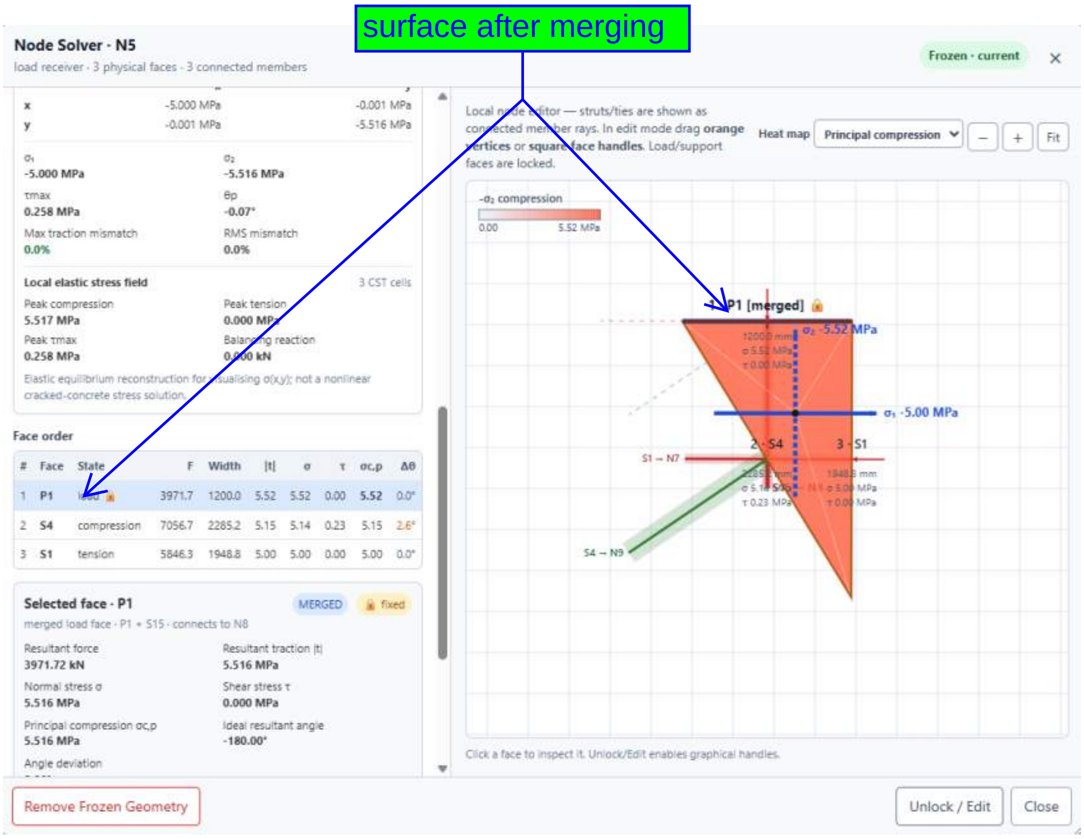


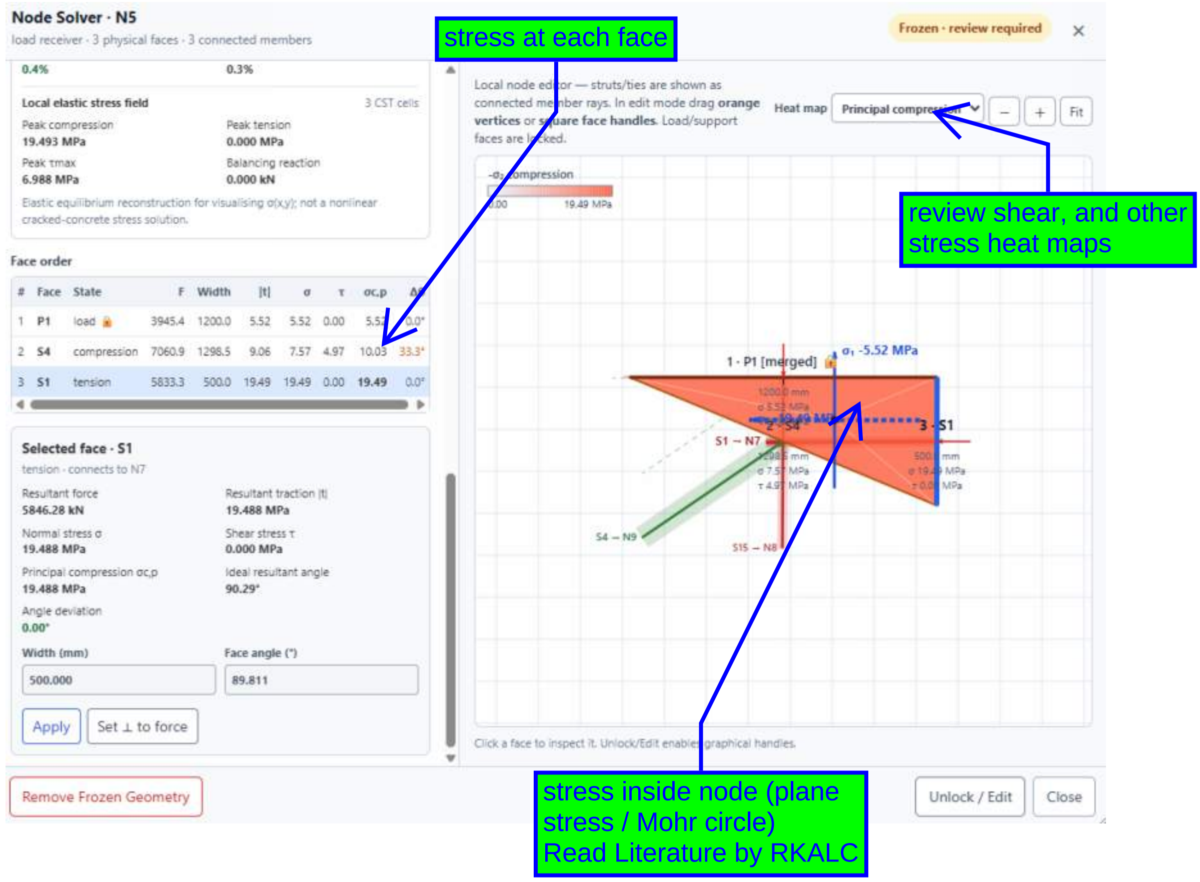
Step 4 - Review Each node and Stress Check





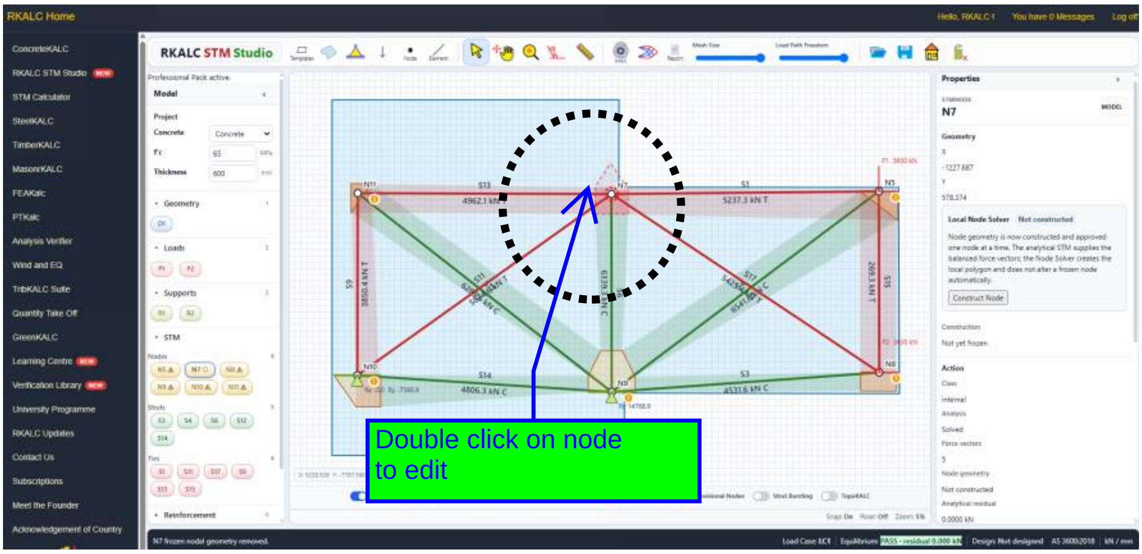
Step 4 - Continued ..

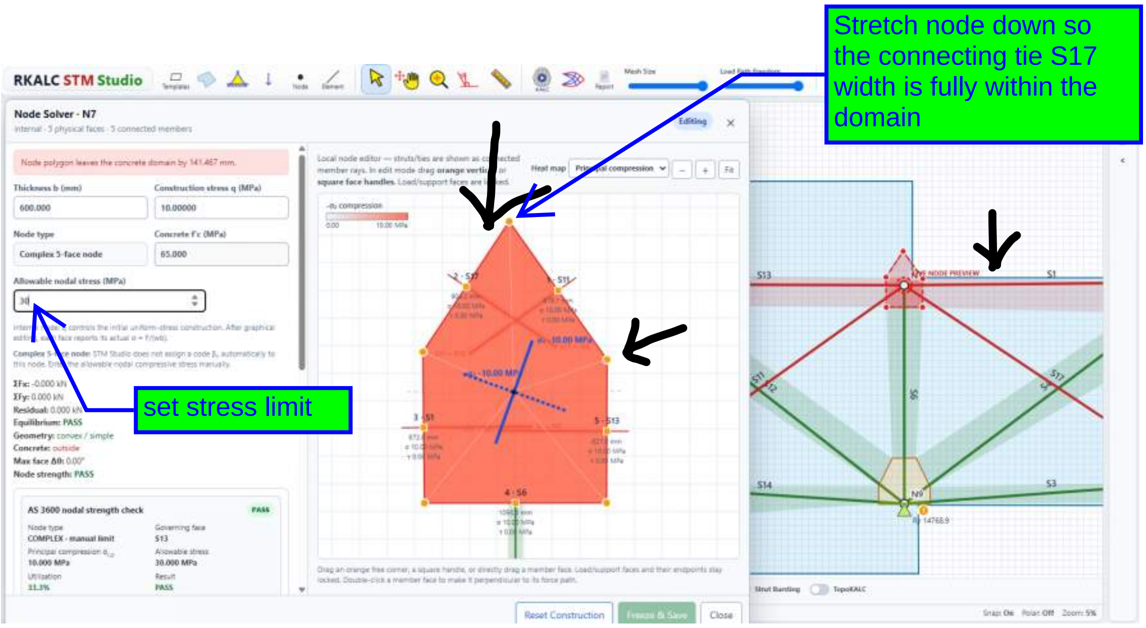


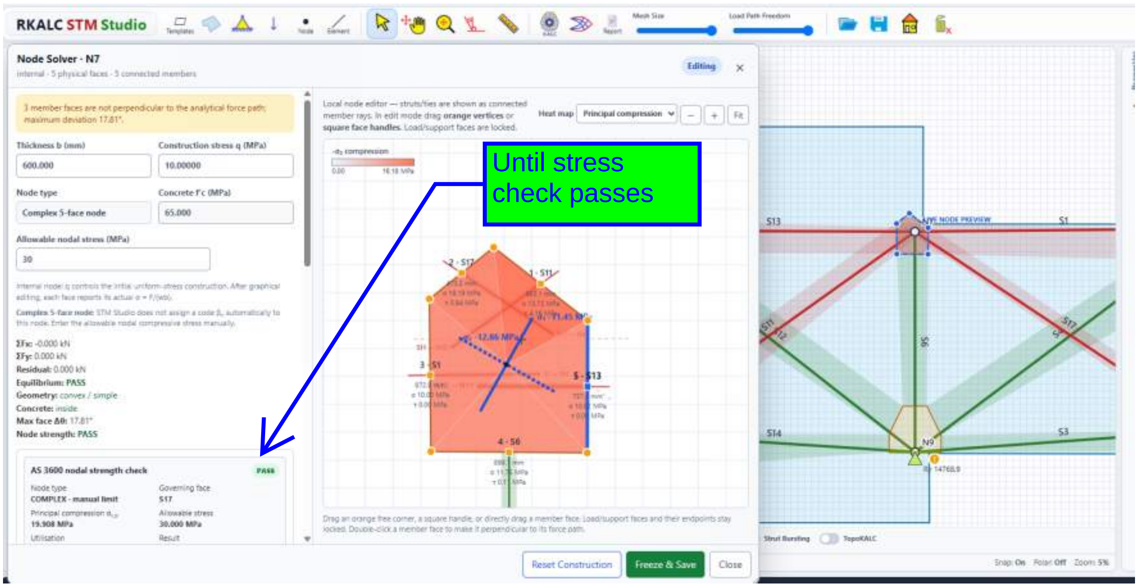


RKALC STRUCTURAL ENGINEERING LEARNING CENTRE	Outrigger Wall Design	By	RK
	STM Studio Worked Example	Sheet No. 10	Date 8/26

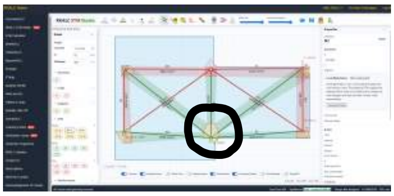
Step 4 - Continued ..

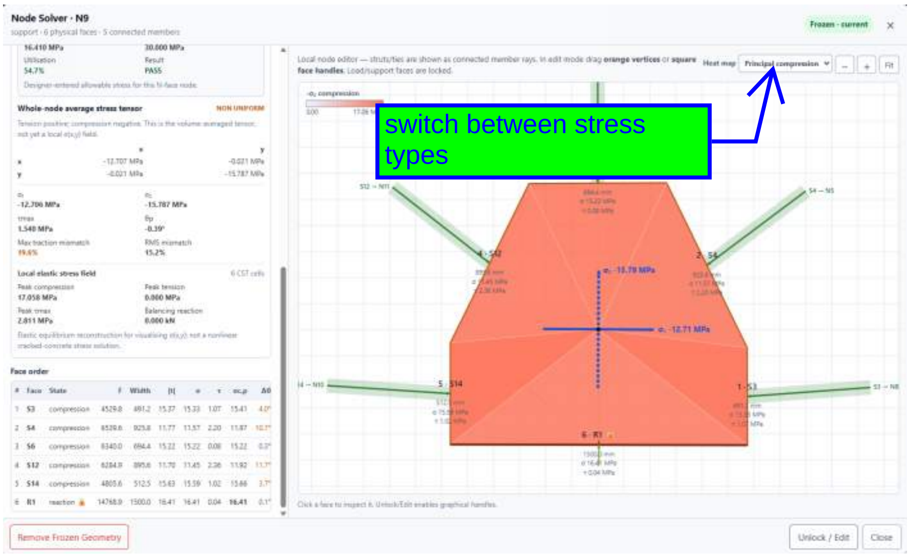


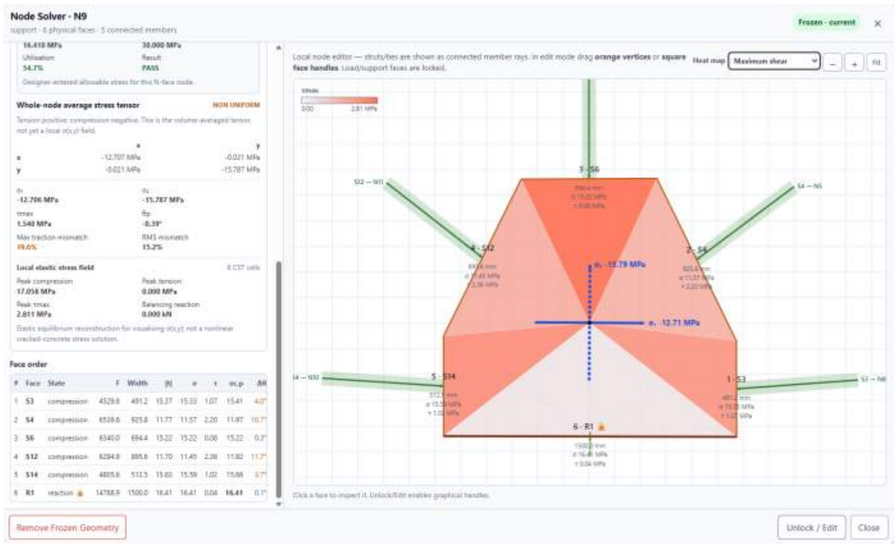


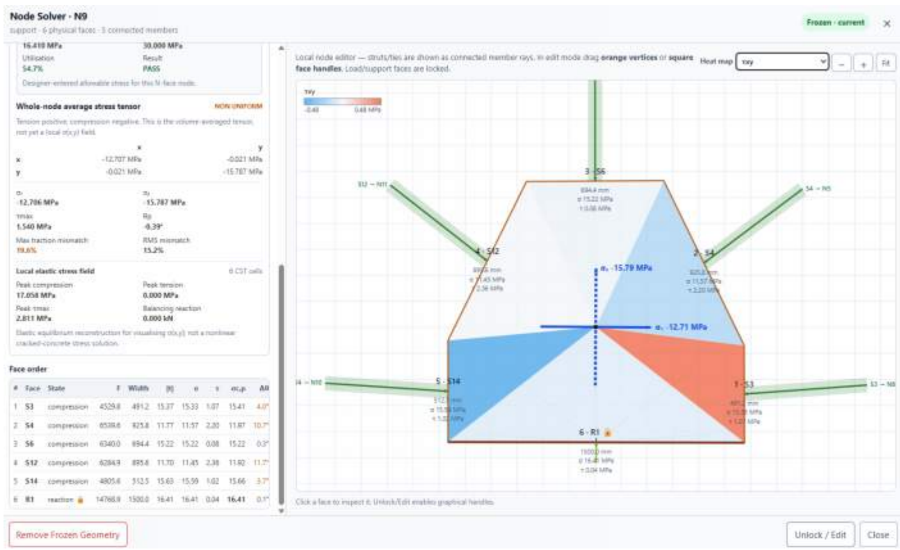


Step 4 - Continued ..







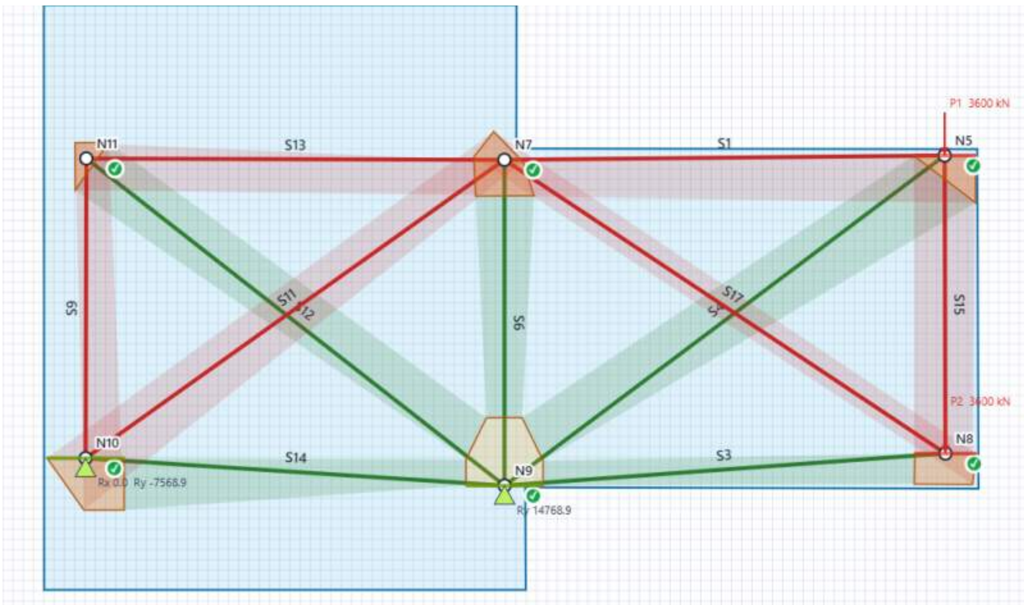


Step 4 - Continued ..

Repeat, until all nodes are fully within the domain and all stress checks pass

Nodes · AS 3600 Cl. 7.4.2

Node	Geometry	Type	Governing face	σc,p	Allowable	Utilisation	Status
N5	Frozen	CCT	S1	9.49 MPa	30.42 MPa	31.2%	PASS
N7	Frozen	COMPLEX	S17	14.28 MPa	30.00 MPa	47.6%	PASS
N8	Frozen	COMPLEX	S17	16.15 MPa	30.00 MPa	53.8%	PASS
N9	Frozen	COMPLEX	R1	16.41 MPa	30.00 MPa	54.7%	PASS
N10	Frozen	COMPLEX	R2	8.41 MPa	30.00 MPa	28.0%	PASS
N11	Frozen	CTT	S9	9.80 MPa	22.82 MPa	43.0%	PASS

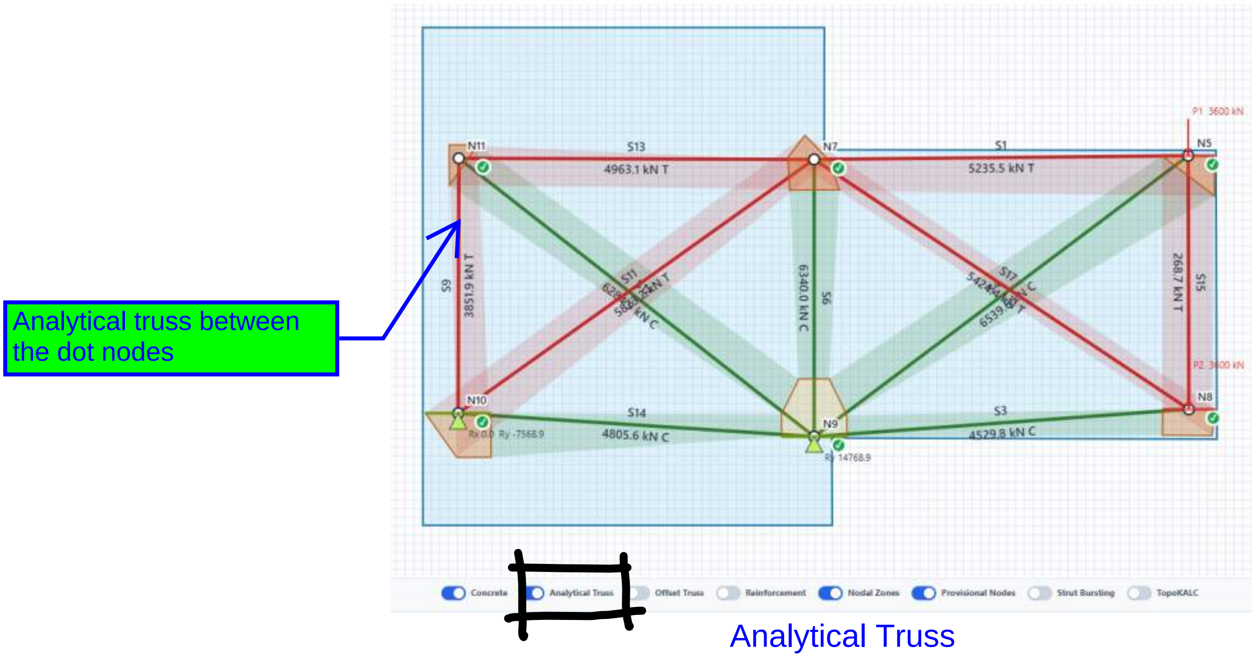


Refer to RKALC Technical Note on N-Face node stress calculations at Learning Centre (scan code below)

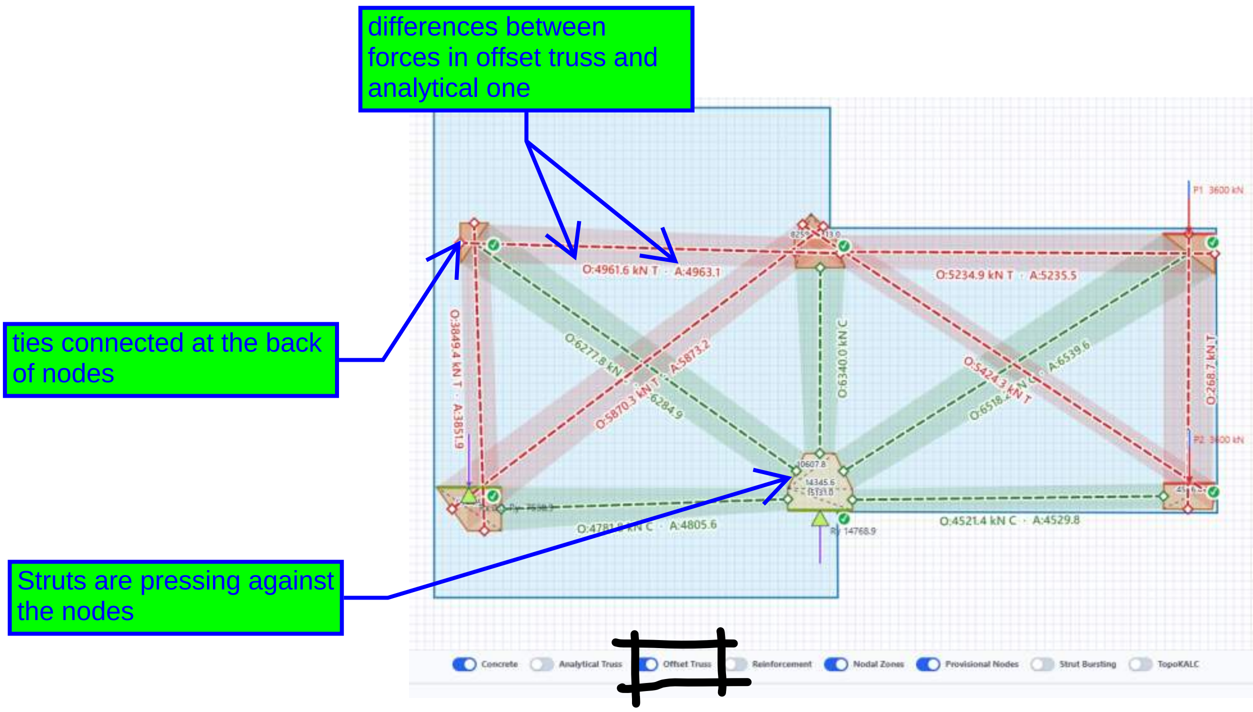
Step 5 - Offset Truss Review

The offset truss is a downstream physical interpretation of the analytical STM.

Once the finite nodal zones have been constructed, each analytical strut or tie is connected between its actual nodal-face application points rather than between idealised node points. The resulting offset axis represents the physical force-transfer path between nodal zones, while the original analytical truss remains the governing equilibrium model.

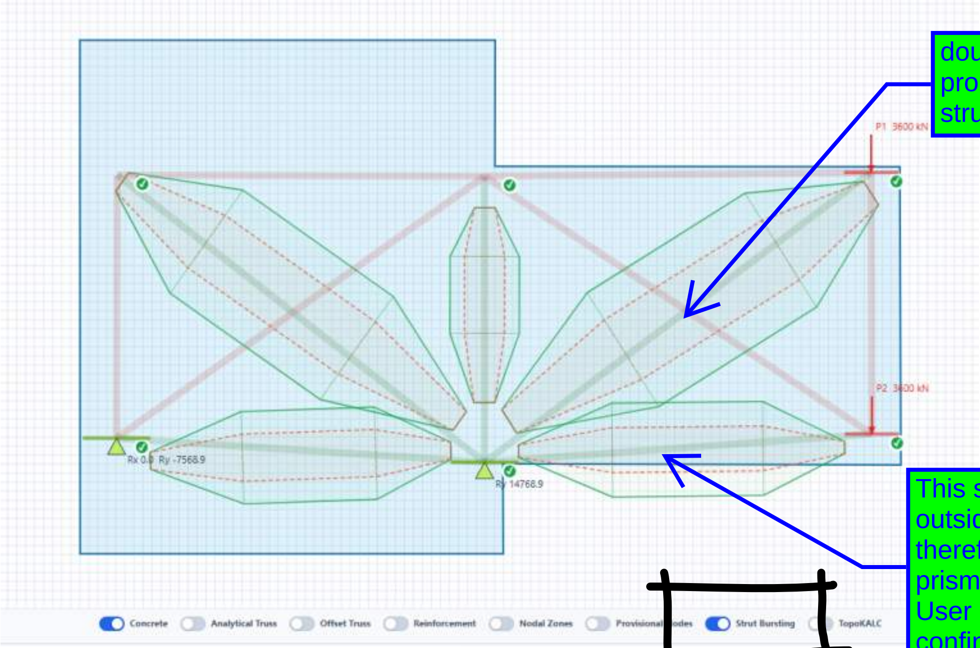


Analytical Truss



Offset Truss

Step 6 - Strut Checks



S4 - Strut Check AS 3600:2018 Section 7

SLS = ~ ULS/1.3 or insert number

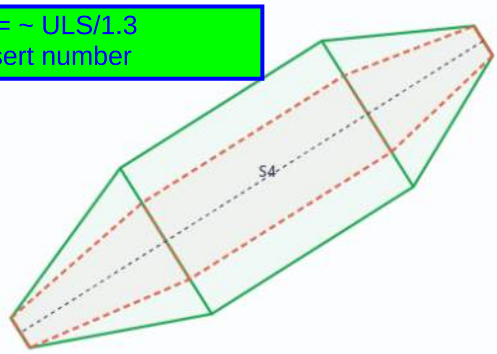
Design inputs

Compression field	Bottle-shaped
φst - AS 3600	0.65
fct used for bursting	0.36√f'c
SLS compression force (kN)	5013

AS 3600:2018: βs = 1.0 for a prismatic strut. For unconfined fan/bottle fields, βs is obtained from Cl. 7.2.2 using the smallest connected strut/tie angle. Design stress = φst βs 0.9f'c and Ac is the smallest strut area normal to its axis (Cl. 7.2.3). Where a tie intersects the strut, θ must also satisfy the 30° minimum in Cl. 7.1(g).

SLS force is not inferred from the present single solved load set. Enter the service compression force when a service bursting check is required.

Bottle-shaped bursting geometry



Frozen nodal face centres. The main canvas can display the SLS and ULS bottle-strut bursting envelopes using the "Strut Bursting" toggle.

AS 3600 strut strength check · Cl. 7.1(g), 7.2.2 & 7.2.3

Compression field	**Bottle-shaped**	
ULS compression force	**6518.21**	kN
Force basis	**Offset physical strut force**	
Strut length L	**9488.6**	mm
End width w1	**1513.3**	mm
End width w2	**925.8**	mm
Smallest width	**925.8**	mm
Area Ac · smallest section	**555453**	mm²
Governing θ for βs	**32.48 (N5/S1)**	deg
βs · Cl. 7.2.2	**0.380**	

Bursting actions

Average Dc	**1219.5**	mm
Bursting length lb	**8269.0**	mm
fct	**2.902**	MPa
Tb,cr = 0.7 b lb fct	**10080.1**	kN
ULS tan α · minimum	**0.200**	
ULS bursting force	**1303.6**	kN
SLS tan α · minimum	**0.500**	
SLS compression force	**5013.0**	kN

Step 6 - Strut Checks

Bursting reinforcement · Cl. 7.2.4

ULS steel fy (MPa) 500 **SLS stress fsi (MPa)** 250

Ax · X-direction reo (mm^2) 0 **Ay · Y-direction reo (mm^2)** 0

Auto size equal Ax = Ay φ = 0.85 for ULS reinforcement resistance

Two orthogonal reinforcement systems are checked together: Ax in global X and Ay in global Y. Areas are the total steel crossing the bursting zone (combined across both wall faces where applicable) and are to be evenly distributed over lb. fsi is the designer's serviceability reinforcement stress from Cl. 12.7.

Reinforcement required?	**NO**	
Trigger T*b · tan α = 1/2	**3259.1**	kN
Trigger limit · 0.5 Tb,cr	**5040.0**	kN
γx · X reo to strut	**32.19**	deg
γy · Y reo to strut	**57.81**	deg
Equal Ax = Ay required · ULS	**2224**	mm^2
Equal Ax = Ay required · SLS	**29238**	mm^2
Governing equal area	**29238**	mm^2 each
Minimum Ax with current Ay	**75676**	mm^2
Minimum Ay with current Ax	**47646**	mm^2
ULS demand	**1303.6**	kN
ULS capacity · φΣAs fy sinγ	**0.0**	kN
ULS utilisation	**—**	%
ULS reinforcement check	**N/A**	
SLS demand · max(T*b,s, Tb,cr)	**10080.1**	kN

click on button to find reo required,
in this strut no bursting is required, however for strut S6, it is required

SLS bursting force 4145.3 kN

Bursting reinforcement · Cl. 7.2.4

ULS steel fy (MPa) 500 **SLS stress fsi (MPa)** 250

Ax · X-direction reo (mm^2) 16538 **Ay · Y-direction reo (mm^2)** 16538

Auto size equal Ax = Ay φ = 0.85 for ULS reinforcement resistance

Two orthogonal reinforcement systems are checked together: Ax in global X and Ay in global Y. Areas are the total steel crossing the bursting zone (combined across both wall faces where applicable) and are to be evenly distributed over lb. fsi is the designer's serviceability reinforcement stress from Cl. 12.7.

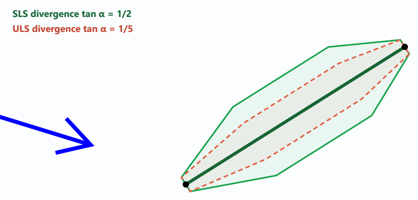
Reinforcement required?	**YES**	
Trigger T*b · tan α = 1/2	**3170.0**	kN
Trigger limit · 0.5 Tb,cr	**2072.7**	kN
γx · X reo to strut	**89.85**	deg

review all values,

Strut S4

N5 → N9
Frozen nodal face centres

PASS



$\sigma^*_{strut} = N^* \times 1000 / A_c = 6518.21 \times 1000 / 555453 = \mathbf{11.73\ MPa}$

$f_{strut,d} = \varphi_{st}\, \beta_s\, 0.9f'_c = 0.65 \times 0.380 \times 0.9 \times 65.0 = \mathbf{14.46\ MPa}$

Refer to Australian Standard AS3600-2018

Calculation item	Result
Compression field	Bottle-shaped
Adopted force, N*	6518.21 kN
Force basis	Offset physical strut force
Physical length, L	9488.6 mm
End width w1	1513.3 mm
End width w2	925.8 mm
Smallest width	925.8 mm
Effective area Ac · smallest section	555453 mm²
Governing θ for βs	32.48°
βs · Cl. 7.2.2	0.380
βs basis	governing θ = 32.48°
Governing strut/tie pair	N5 / S1
Strut/tie angle · Cl. 7.1(g)	32.48° · PASS (≥ 30°)
φst	0.65
f'c	65.0 MPa
Allowable design stress φst βs 0.9f'c	14.46 MPa
Applied strut stress N*/Ac	11.73 MPa
Design strut capacity φNus	8033.4 kN
Concrete strut utilisation	81.1%
Overall AS 3600 strut result	PASS

Bottle-shaped bursting actions · AS 3600 Cl. 7.2.4

Bursting action	Value
Average Dc	1219.5 mm
Bursting length Lb	8269.0 mm
fct	2.902 MPa
Tb,cr = 0.7 b Lb fct	10080.1 kN
ULS divergence	tan α = 1/5
ULS bursting force	1303.6 kN
SLS divergence	tan α = 1/2
SLS compression force	5013.0 kN
SLS bursting force	10080.1 kN

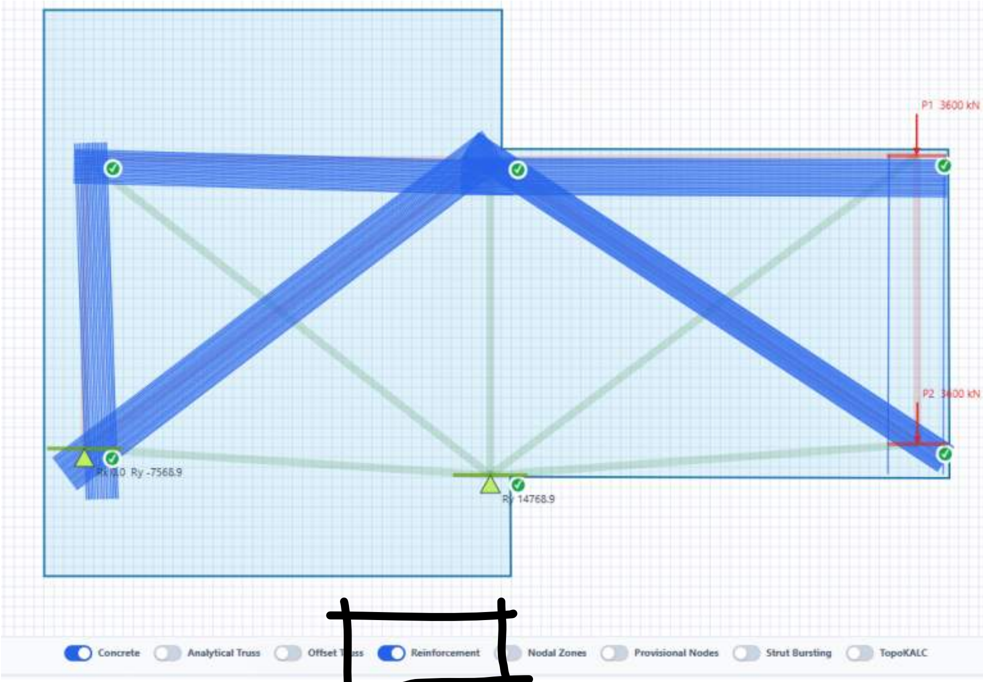
Two-direction bursting reinforcement · X / Y

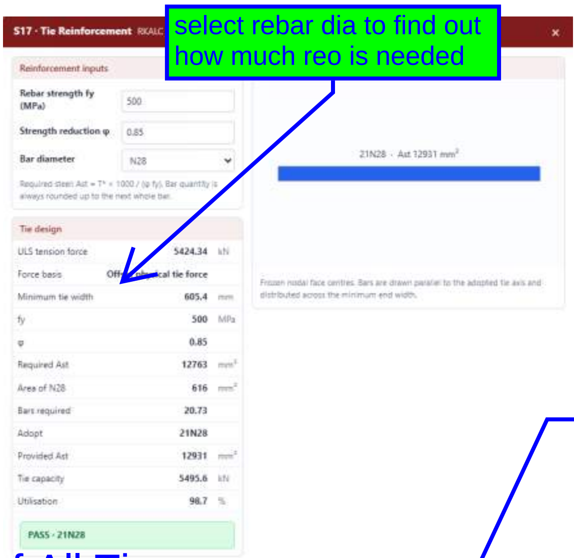
Transverse bursting reinforcement not required: T*b(tan α = 1/2) = 3259.1 kN ≤ 0.5Tb,cr = 5040.0 kN.

Summary of All Struts:

Strut	N*	Shape	βs	θmin	σ* / allowable	Concrete util.	Bursting Ax / Ay	Bursting reo	Overall
S3	4521.4 kN	prismatic	1.000	34.1°	15.34 / 38.03 MPa	40.3%	N/A	N/A	PASS
S4	6518.2 kN	bottle	0.380	32.5°	11.73 / 14.46 MPa	81.1%	N/A	NOT REQUIRED	PASS
S6	6340.0 kN	bottle	0.722	52.6°	15.22 / 27.44 MPa	55.5%	Ax 16538 / Ay 16538 mm²	PASS	PASS
S12	6277.8 kN	bottle	0.402	33.7°	11.68 / 15.30 MPa	76.3%	N/A	NOT REQUIRED	PASS
S14	4781.8 kN	bottle	0.431	35.3°	15.55 / 16.40 MPa	94.8%	N/A	NOT REQUIRED	PASS

Step 7 - Ties





Note if reo is too much, use high strength rebar such as Macalloy or Freyssibar with end plates
All reo must be developed

Summary of All Ties:

Ties

Tie	T*	Ast,req	Adopt	Utilisation	Status
S1	5234.9 kN	12317 mm²	21N28	95.3%	PASS
S11	5870.3 kN	13812 mm²	23N28	97.5%	PASS
S17	5424.3 kN	12763 mm²	21N28	98.7%	PASS
S9	3849.4 kN	9057 mm²	15N28	98.1%	PASS
S13	4961.6 kN	11674 mm²	19N28	99.8%	PASS
S15	268.7 kN	632 mm²	2N28	51.3%	PASS

Step 7 - Ties

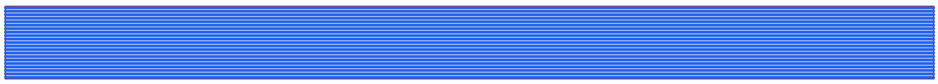
Tie S1

N5 → N7

Frozen nodal face centres

PASS

21N28 · Ast,prov 12931 mm²



Frozen nodal face centres

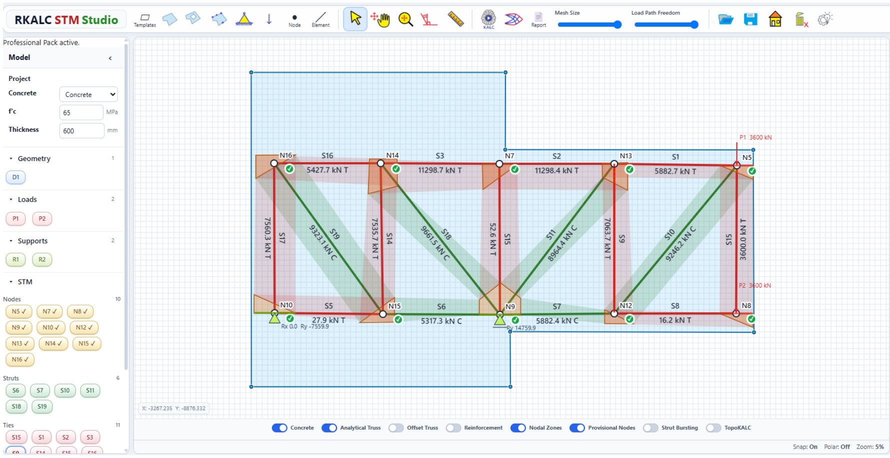
$A_{st,req} = T^* \times 1000 / (\varphi f_y) = 5234.93 \times 1000 / (0.85 \times 500) = \mathbf{12317\ mm^2}$

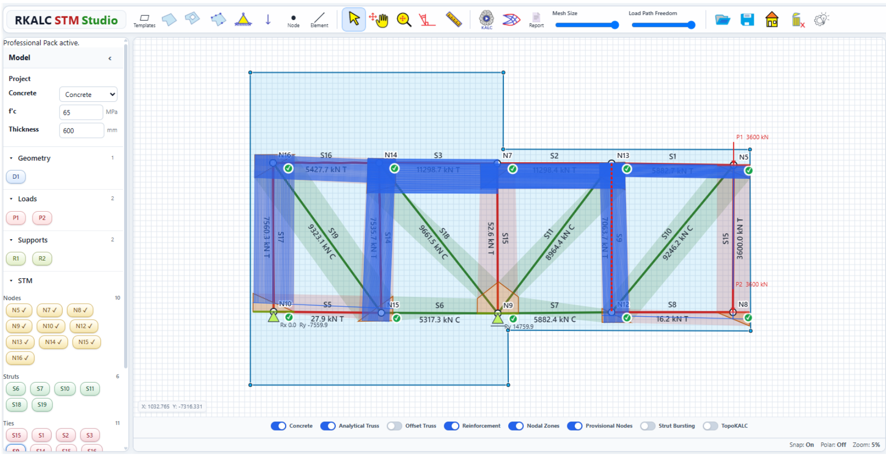
Calculation item	Result
ULS tension T*	5234.93 kN
Force basis	Offset physical tie force
Minimum tie width	755.2 mm
fy	500 MPa
φ	0.85
Required Ast	12317 mm²
Area of N28	616 mm²
Exact bars required	20.00
Adopt	21N28
Provided Ast	12931 mm²
Tie capacity	5495.6 kN
Utilisation	95.3%

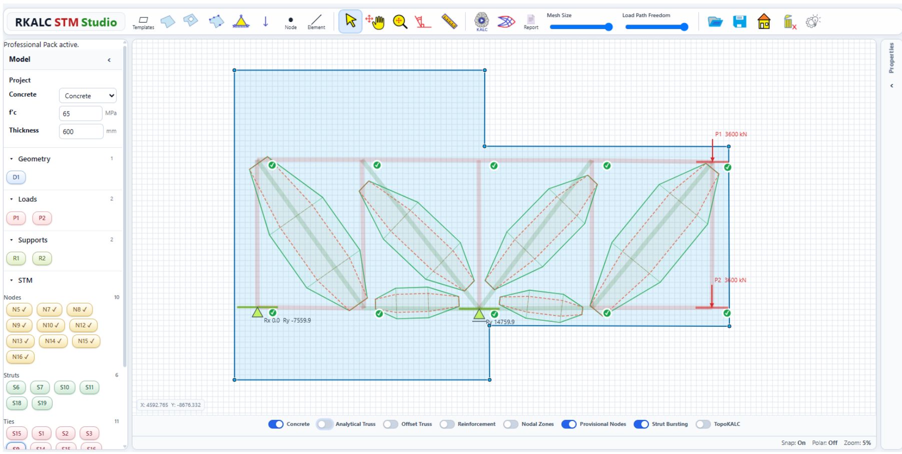
> **AS 3600:2018:** Tie reinforcement must be fully developed past the nodal zone so that the required design tie force is properly anchored at the node.

Other Options and NOTES

another load path is in the screen shot below, there you can eliminate the need for inclined reinforcement and converting the matter to vertical tension (which is essentially shear inspired, just like coupling beams).
note also the outrigger loads are reversal, so the same problem should be mirrored. you will need to get equal tension reo at top and bottom to counter the lateral force in both direction.







Appendix - Design Report

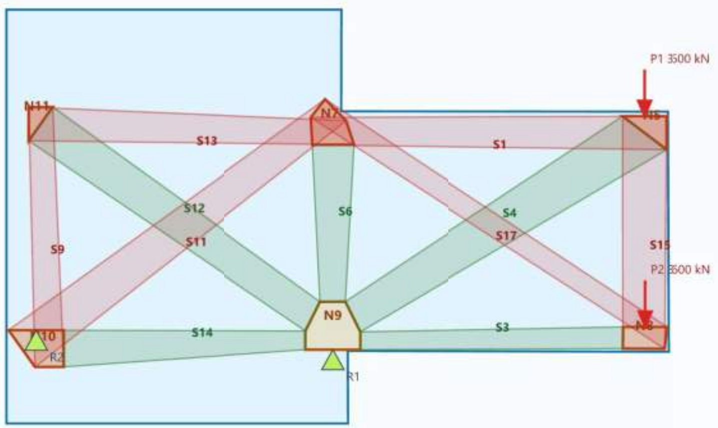
RKALC STM Studio

Strut-and-Tie Model Analysis and Design

PASS

REPORT DATE **19 Aug 2026, 02:51 pm**	ANALYSIS **Solved**
METHOD **2D truss stiffness**	MAXIMUM RISIDUAL **0.0000 kN**
CONCRETE F'C **65.0 MPa**	THICKNESS **600.0 mm**
NODES **6**	STRUTS / TIES **5 / 6**

1. Strut-and-Tie Model



Overview shows the concrete domain, openings, frozen nodal zones, applied loads, supports, and the non-prismatic physical strut/tie envelopes joining the full nodal faces. Analytical and offset centre-lines are intentionally omitted.

2. Analysis Basis

2D pin-jointed truss: $K u = F$ | member axial force recovered from EA/L compatibility.

Member	Type	Node I	Node J	Length	Axial force	State
S3	strut	N8	N9	8611.8 mm	-4529.78 kN	compression
S4	strut	N5	N9	10711.1 mm	-6539.59 kN	compression
S6	strut	N7	N9	6336.4 mm	-6340.01 kN	compression
S12	strut	N11	N9	10338.9 mm	-6284.92 kN	compression
S14	strut	N9	N10	8180.5 mm	-4805.60 kN	compression
S1	tie	N5	N7	8577.2 mm	5235.50 kN	tension
S11	tie	N7	N10	10013.3 mm	5873.24 kN	tension
S17	tie	N7	N8	10318.1 mm	5424.37 kN	tension
S9	tie	N10	N11	5830.1 mm	3851.86 kN	tension
S13	tie	N7	N11	8145.8 mm	4963.07 kN	tension
S15	tie	N8	N5	5796.6 mm	268.68 kN	tension

Analysis messages

- INFO: Statically indeterminate STM (degree 2). Forces are solved by 2D truss stiffness and compatibility.

3. Applied Loads and Reactions

Applied actions

Load	Node	Fx	Fy	Contact width
P1	N5	0.00 kN	-3600.00 kN	1200.0 mm
P2	N8	0.00 kN	-3600.00 kN	1200.0 mm

Support reactions

Support	Node	Rx	Ry
R1	N9	—	14768.93 kN
R2	N10	0.00 kN	-7568.93 kN

4. Design Summary

Struts · AS 3600 Section 7

Strut	N*	Shape	βs	θmin	σ* / allowable	Concrete util.	Bursting Ax / Ay	Bursting reo	Overall
S3	4521.4 kN	prismatic	1.000	34.1°	15.34 / 38.03 MPa	40.3%	N/A	N/A	PASS
S4	6518.2 kN	bottle	0.380	32.5°	11.73 / 14.46 MPa	81.1%	N/A	NOT REQUIRED	PASS
S6	6340.0 kN	bottle	0.722	52.6°	15.22 / 27.44 MPa	55.5%	Ax 16538 / Ay 16538 mm^2	PASS	PASS
S12	6277.8 kN	bottle	0.402	33.7°	11.68 / 15.30 MPa	76.3%	N/A	NOT REQUIRED	PASS
S14	4781.8 kN	bottle	0.431	35.3°	15.55 / 16.40 MPa	94.8%	N/A	NOT REQUIRED	PASS

Ties

Tie	T*	Ast,req	Adopt	Utilisation	Status
S1	5234.9 kN	12317 mm^2	21N28	95.3%	PASS
S11	5870.3 kN	13812 mm^2	23N28	97.5%	PASS
S17	5424.3 kN	12763 mm^2	21N28	98.7%	PASS
S9	3849.4 kN	9057 mm^2	15N28	98.1%	PASS
S13	4961.6 kN	11674 mm^2	19N28	99.8%	PASS
S15	268.7 kN	632 mm^2	2N28	51.3%	PASS

Nodes · AS 3600 Cl. 7.4.2

Node	Geometry	Type	Governing face	σc,p	Allowable	Utilisation	Status
N5	Frozen	CCT	S1	9.49 MPa	30.42 MPa	31.2%	PASS
N7	Frozen	COMPLEX	S17	14.28 MPa	30.00 MPa	47.6%	PASS
N8	Frozen	COMPLEX	S17	16.15 MPa	30.00 MPa	53.8%	PASS
N9	Frozen	COMPLEX	R1	16.41 MPa	30.00 MPa	54.7%	PASS
N10	Frozen	COMPLEX	R2	8.41 MPa	30.00 MPa	28.0%	PASS
N11	Frozen	CTT	S9	9.80 MPa	22.82 MPa	43.0%	PASS

5. Strut Calculations

Strut S3

N8 → N9 PASS

Frozen nodal face centres

Prismatic compression field

Clause 7.2.4 bottle-strut bursting check not applicable.

$\sigma^*_{strut} = N^* \times 1000 / A_c = 4521.35 \times 1000 / 294720 =$

$f_{strut,d} = \varphi_{st}\, \beta_s\, 0.9f'_c = 0.65 \times 1.000 \times 0.9 \times 65.0 =$

Calculation item	Result
Compression field	Prismatic
Adopted force, N*	4521.35 kN
Force basis	Offset physical strut force
Physical length, L	7236.3 mm
End width w1	593.3 mm
End width w2	491.2 mm
Smallest width	491.2 mm
Effective area Ac · smallest section	294720 mm²
Governing θ for βs	34.09°
βs · Cl. 7.2.2	1.000
βs basis	βs = 1.0 · AS 3600 Cl. 7.2.2
Governing strut/tie pair	N8 / S17
Strut/tie angle · Cl. 7.1(g)	34.09° · PASS (≥ 30°)
φst	0.65
f'c	65.0 MPa
Allowable design stress φst βs 0.9f'c	38.03 MPa
Applied strut stress N*/Ac	15.34 MPa
Design strut capacity φNus	11206.7 kN
Concrete strut utilisation	40.3%
Overall AS 3600 strut result	**PASS**

Clause 7.2.4 bottle-shaped bursting reinforcement check is not applied to this prismatic strut.

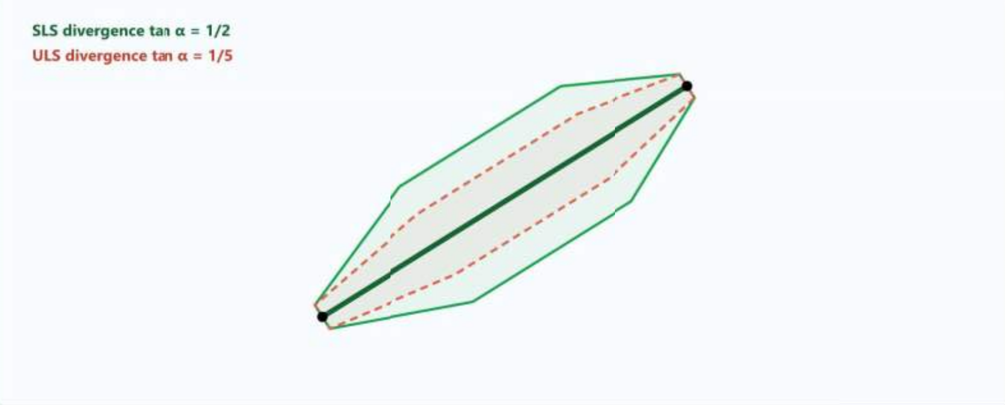
• PASS · AS 3600 strut stress and strut/tie angle requirements satisfied.

Strut S4

N5 → N9

Frozen nodal face centres

PASS



$\sigma^*_{strut} = N^* \times 1000 / A_c = 6518.21 \times 1000 / 555453 =$

$f_{strut,d} = \varphi_{st}\, \beta_s\, 0.9f_c = 0.65 \times 0.380 \times 0.9 \times 65.0 =$

Calculation item	Result
Compression field	Bottle-shaped
Adopted force, N*	6518.21 kN
Force basis	Offset physical strut force
Physical length, L	9488.6 mm
End width w1	1513.3 mm
End width w2	925.8 mm
Smallest width	925.8 mm
Effective area Ac · smallest section	555453 mm²
Governing θ for βs	32.48°
βs · Cl. 7.2.2	0.380
βs basis	governing θ = 32.48°
Governing strut/tie pair	N5 / S1
Strut/tie angle · Cl. 7.1(g)	32.48° · PASS (≥ 30°)
φst	0.65
f'c	65.0 MPa
Allowable design stress φst βs 0.9f'c	14.46 MPa
Applied strut stress N*/Ac	11.73 MPa
Design strut capacity φNus	8033.4 kN
Concrete strut utilisation	81.1%
Overall AS 3600 strut result	**PASS**

Bottle-shaped bursting actions · AS 3600 Cl. 7.2.4

Bursting action	Value
Average Dc	1219.5 mm
Bursting length Lb	8269.0 mm
fct	2.902 MPa
Tb,cr = 0.7 b Lb fct	10080.1 kN
ULS divergence	tan α = 1/5
ULS bursting force	1303.6 kN
SLS divergence	tan α = 1/2
SLS compression force	5013.0 kN
SLS bursting force	10080.1 kN

Two-direction bursting reinforcement · X / Y

Transverse bursting reinforcement not required: T*b(tan α = 1/2) = 3259.1 kN ≤ 0.5Tb,cr = 5040.0 kN.

Reinforcement check item	Result
Transverse reinforcement required?	NO · NOT REQUIRED
Trigger force · T*b at tan α = 1/2	3259.1 kN
Trigger limit · 0.5 Tb,cr	5040.0 kN
X-direction reinforcement Ax	0 mm²
Y-direction reinforcement Ay	0 mm²
γx · X reinforcement to strut	32.19°
γy · Y reinforcement to strut	57.81°
Weighted steel area Ax sinγx + Ay sinγy	0.0 mm²
ULS reinforcement φ	0.85
ULS steel fy	500 MPa
SLS reinforcement stress fsi	250 MPa
Equal Ax = Ay required · ULS	2224 mm² each
Equal Ax = Ay required · SLS	29238 mm² each
Governing equal Ax = Ay	29238 mm² each
Minimum Ax with current Ay	75676 mm²
Minimum Ay with current Ax	47646 mm²
ULS demand	1303.6 kN
ULS reinforcement capacity	0.0 kN
ULS utilisation	0.0%
ULS reinforcement result	N/A
SLS demand · max(T*b,s, Tb,cr)	10080.1 kN
SLS reinforcement capacity	0.0 kN
SLS utilisation	0.0%
SLS reinforcement result	N/A
Bursting reinforcement result	NOT REQUIRED

A_x and A_y are the total reinforcement areas crossing the bursting zone in the global X and Y directions. Their contributions are interconnected through the angle of each reinforcement system to the strut. Where reinforcement is provided on both wall faces, the reported areas are the combined total areas. Reinforcement is to be evenly distributed through the bursting length L_b.

• PASS · AS 3600 strut stress and strut/tie angle requirements satisfied.

Strut S6

N7 → N9

Frozen nodal face centres

PASS

$\sigma^*_{strut} = N^* \times 1000 / A_c = 6339.98 \times 1000 / 416623 =$

$f_{strut,d} = \varphi_{st}\, \beta_s\, 0.9 f_c = 0.65 \times 0.722 \times 0.9 \times 65.0 =$

Calculation item	Result
Compression field	Bottle-shaped
Adopted force, N*	6339.98 kN
Force basis	Offset physical strut force
Physical length, L	4316.1 mm
End width w1	1136.7 mm
End width w2	694.4 mm
Smallest width	694.4 mm
Effective area Ac · smallest section	416623 mm²
Governing θ for βs	52.60°
βs · Cl. 7.2.2	0.722
βs basis	governing θ = 52.60°
Governing strut/tie pair	N7 / S11
Strut/tie angle · Cl. 7.1(g)	52.60° · PASS (≥ 30°)
φst	0.65
f'c	65.0 MPa
Allowable design stress φst βs 0.9f'c	27.44 MPa
Applied strut stress N*/Ac	15.22 MPa
Design strut capacity φNus	11432.0 kN
Concrete strut utilisation	55.5%
Overall AS 3600 strut result	PASS

Bottle-shaped bursting actions · AS 3600 Cl. 7.2.4

Bursting action	Value
Average Dc	915.5 mm
Bursting length Lb	3400.6 mm
fct	2.902 MPa
Tb,cr = 0.7 b Lb fct	4145.3 kN
ULS divergence	tan α = 1/5
ULS bursting force	1268.0 kN
SLS divergence	tan α = 1/2
SLS compression force	4876.0 kN
SLS bursting force	4145.3 kN

Two-direction bursting reinforcement · X / Y

PASS · adopted X/Y bursting reinforcement satisfies both ULS and SLS requirements.

$R_{ULS} = \varphi\, f_y [A_x \sin\gamma_x + A_y \sin\gamma_y]$

$= 0.85 \times 500 \times [16538 \times 1.0000 + 16538 \times 0.0027] / 1000 = \quad \geq$

$R_{SLS} = f_{si} [A_x \sin\gamma_x + A_y \sin\gamma_y]$

$= 250 \times [16538 \times 1.0000 + 16538 \times 0.0027] / 1000 = \quad \geq$

Reinforcement check item	Result
Transverse reinforcement required?	YES · REINFORCEMENT REQUIRED
Trigger force · T*b at tan α = 1/2	3170.0 kN
Trigger limit · 0.5 Tb,cr	2072.7 kN
X-direction reinforcement Ax	16538 mm²
Y-direction reinforcement Ay	16538 mm²
γx · X reinforcement to strut	89.85°
γy · Y reinforcement to strut	0.15°
Weighted steel area Ax sinγx + Ay sinγy	16582.0 mm²
ULS reinforcement φ	0.85
ULS steel fy	500 MPa
SLS reinforcement stress fsi	250 MPa
Equal Ax = Ay required · ULS	2976 mm² each
Equal Ax = Ay required · SLS	16537 mm² each
Governing equal Ax = Ay	16537 mm² each
Minimum Ax with current Ay	16537 mm²
Minimum Ay with current Ax	16292 mm²
ULS demand	1268.0 kN
ULS reinforcement capacity	7047.3 kN
ULS utilisation	18.0%
ULS reinforcement result	PASS
SLS demand · max(T*b,s, Tb,cr)	4145.3 kN
SLS reinforcement capacity	4145.5 kN
SLS utilisation	100.0%
SLS reinforcement result	PASS
Bursting reinforcement result	PASS

A_x and A_y are the total reinforcement areas crossing the bursting zone in the global X and Y directions. Their contributions are interconnected through the angle of each reinforcement system to the strut. Where reinforcement is provided on both wall faces, the reported areas are the combined total areas. Reinforcement is to be evenly distributed through the bursting length L_b.

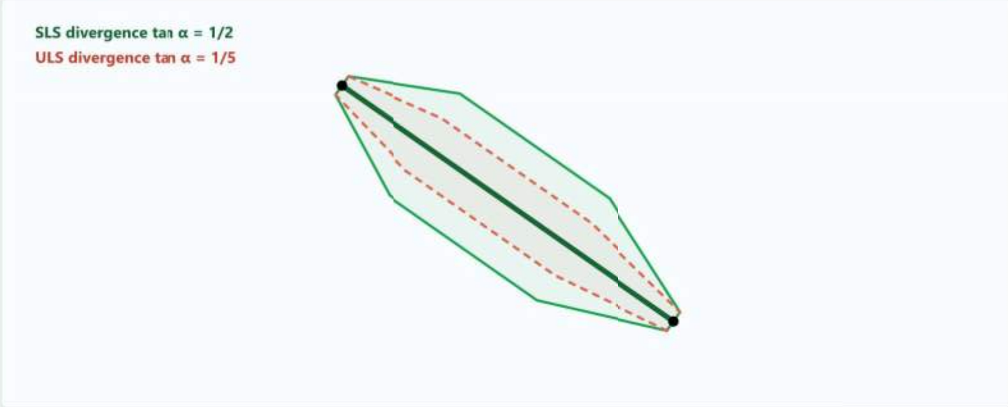
• PASS · AS 3600 strut strength, angle and bottle-strut bursting reinforcement requirements satisfied.

Strut S12

N11 → N9

Frozen nodal face centres

PASS



$$\sigma^*_{strut} = N^* \times 1000 / A_c = 6277.82 \times 1000 / 537369 =$$
$$f_{strut,d} = \varphi_{st}\, \beta_s\, 0.9 f'_c = 0.65 \times 0.402 \times 0.9 \times 65.0 =$$

Calculation item	Result
Compression field	Bottle-shaped
Adopted force, N*	6277.82 kN
Force basis	Offset physical strut force
Physical length, L	9170.2 mm
End width w1	1134.1 mm
End width w2	895.6 mm
Smallest width	895.6 mm
Effective area Ac · smallest section	537369 mm²
Governing θ for βs	33.69°
βs · Cl. 7.2.2	0.402
βs basis	governing θ = 33.69°
Governing strut/tie pair	N11 / S13
Strut/tie angle · Cl. 7.1(g)	33.69° · PASS (≥ 30°)
φst	0.65
f'c	65.0 MPa
Allowable design stress φst βs 0.9f'c	15.30 MPa
Applied strut stress N*/Ac	11.68 MPa
Design strut capacity φNus	8223.2 kN
Concrete strut utilisation	76.3%
Overall AS 3600 strut result	PASS

Bottle-shaped bursting actions · AS 3600 Cl. 7.2.4

Bursting action	Value
Average Dc	1014.9 mm
Bursting length Lb	8155.3 mm
fct	2.902 MPa
Tb,cr = 0.7 b Lb fct	9941.4 kN
ULS divergence	tan α = 1/5
ULS bursting force	1255.6 kN
SLS divergence	tan α = 1/2
SLS compression force	4828.0 kN
SLS bursting force	9941.4 kN

Two-direction bursting reinforcement · X / Y

Transverse bursting reinforcement not required: T*b(tan α = 1/2) = 3138.9 kN ≤ 0.5Tb,cr = 4970.7 kN.

Reinforcement check item	Result
Transverse reinforcement required?	NO · NOT REQUIRED
Trigger force · T*b at tan α = 1/2	3138.9 kN
Trigger limit · 0.5 Tb,cr	4970.7 kN
X-direction reinforcement Ax	0 mm²
Y-direction reinforcement Ay	0 mm²
γx · X reinforcement to strut	35.26°
γy · Y reinforcement to strut	54.74°
Weighted steel area Ax sinγx + Ay sinγy	0.0 mm²
ULS reinforcement φ	0.85
ULS steel fy	500 MPa
SLS reinforcement stress fsi	250 MPa
Equal Ax = Ay required · ULS	2120 mm² each
Equal Ax = Ay required · SLS	28530 mm² each
Governing equal Ax = Ay	28530 mm² each
Minimum Ax with current Ay	68887 mm²
Minimum Ay with current Ax	48699 mm²
ULS demand	1255.6 kN
ULS reinforcement capacity	0.0 kN
ULS utilisation	0.0%
ULS reinforcement result	N/A
SLS demand · max(T*b,s, Tb,cr)	9941.4 kN
SLS reinforcement capacity	0.0 kN
SLS utilisation	0.0%
SLS reinforcement result	N/A
Bursting reinforcement result	NOT REQUIRED

> A_x and A_y are the total reinforcement areas crossing the bursting zone in the global X and Y directions. Their contributions are interconnected through the angle of each reinforcement system to the strut. Where reinforcement is provided on both wall faces, the reported areas are the combined total areas. Reinforcement is to be evenly distributed through the bursting length L_b.

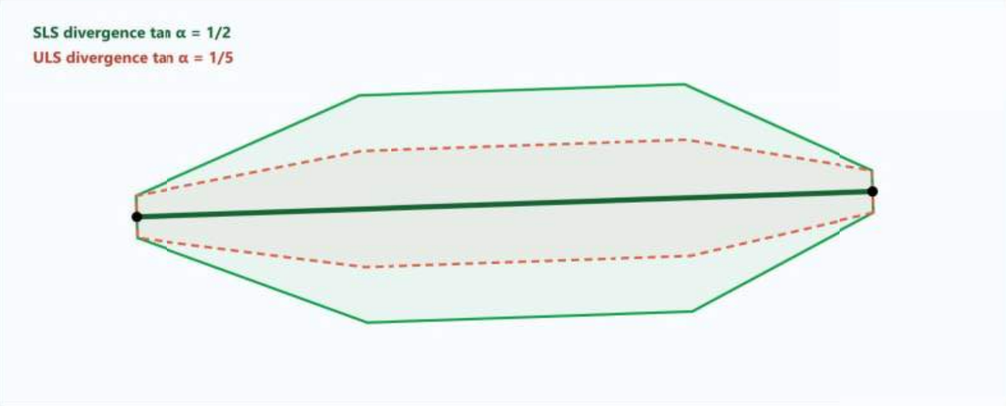
> • PASS · AS 3600 strut stress and strut/tie angle requirements satisfied.

Strut S14

N9 → N10

Frozen nodal face centres

PASS



$\sigma^*_{strut} = N^* \times 1000 / A_c = 4781.83 \times 1000 / 307495 =$

$f_{strut,d} = \varphi_{st}\, \beta_s\, 0.9 f_c = 0.65 \times 0.431 \times 0.9 \times 65.0 =$

Calculation item	Result
Compression field	Bottle-shaped
Adopted force, N*	4781.83 kN
Force basis	Offset physical strut force
Physical length, L	6666.9 mm
End width w1	512.5 mm
End width w2	1004.0 mm
Smallest width	512.5 mm
Effective area Ac · smallest section	307495 mm²
Governing θ for βs	35.28°
βs · Cl. 7.2.2	0.431
βs basis	governing θ = 35.28°
Governing strut/tie pair	N10 / S11
Strut/tie angle · Cl. 7.1(g)	35.28° · PASS (≥ 30°)
φst	0.65
f'c	65.0 MPa
Allowable design stress φst βs 0.9f'c	16.40 MPa
Applied strut stress N*/Ac	15.55 MPa
Design strut capacity φNus	5042.8 kN
Concrete strut utilisation	94.8%
Overall AS 3600 strut result	PASS

Bottle-shaped bursting actions · AS 3600 Cl. 7.2.4

Bursting action	Value
Average Dc	758.2 mm
Bursting length Lb	5908.7 mm
fct	2.902 MPa
Tb,cr = 0.7 b Lb fct	7202.8 kN
ULS divergence	tan α = 1/5
ULS bursting force	956.4 kN
SLS divergence	tan α = 1/2
SLS compression force	3676.0 kN
SLS bursting force	7202.8 kN

Two-direction bursting reinforcement · X / Y

Transverse bursting reinforcement not required: T*b(tan α = 1/2) = 2390.9 kN ≤ 0.5Tb,cr = 3601.4 kN.

Reinforcement check item	Result
Transverse reinforcement required?	NO · NOT REQUIRED
Trigger force · T*b at tan α = 1/2	2390.9 kN
Trigger limit · 0.5 Tb,cr	3601.4 kN
X-direction reinforcement Ax	0 mm²
Y-direction reinforcement Ay	0 mm²
γx · X reinforcement to strut	1.97°
γy · Y reinforcement to strut	88.03°
Weighted steel area Ax sinγx + Ay sinγy	0.0 mm²
ULS reinforcement φ	0.85
ULS steel fy	500 MPa
SLS reinforcement stress fsi	250 MPa
Equal Ax = Ay required · ULS	2177 mm² each
Equal Ax = Ay required · SLS	27871 mm² each
Governing equal Ax = Ay	27871 mm² each
Minimum Ax with current Ay	839098 mm²
Minimum Ay with current Ax	28828 mm²
ULS demand	956.4 kN
ULS reinforcement capacity	0.0 kN
ULS utilisation	0.0%
ULS reinforcement result	**N/A**
SLS demand · max(T*b,s, Tb,cr)	7202.8 kN
SLS reinforcement capacity	0.0 kN
SLS utilisation	0.0%
SLS reinforcement result	**N/A**
Bursting reinforcement result	**NOT REQUIRED**

> A_x and A_y are the total reinforcement areas crossing the bursting zone in the global X and Y directions. Their contributions are interconnected through the angle of each reinforcement system to the strut. Where reinforcement is provided on both wall faces, the reported areas are the combined total areas. Reinforcement is to be evenly distributed through the bursting length L_b.

> • PASS · AS 3600 strut stress and strut/tie angle requirements satisfied.

6. Tie Calculations

Tie S1

N5 → N7
Frozen nodal face centres

PASS

21N28 · Ast,prov 12931 mm²

Frozen nodal face centres

$$A_{st,req} = T^* \times 1000 / (\varphi\, f_y) = 5234.93 \times 1000 / (0.85 \times 500) =$$

Calculation item	Result
ULS tension T*	5234.93 kN
Force basis	Offset physical tie force
Minimum tie width	755.2 mm
fy	500 MPa
φ	0.85
Required Ast	12317 mm²
Area of N28	616 mm²
Exact bars required	20.00
Adopt	21N28
Provided Ast	12931 mm²
Tie capacity	5495.6 kN
Utilisation	95.3%

> **AS 3600:2018:** Tie reinforcement must be fully developed past the nodal zone so that the required design tie force is properly anchored at the node.

Tie S11

N7 → N10

Frozen nodal face centres

PASS

23N28 · Ast,prov 14162 mm²

Frozen nodal face centres

$A_{st,req} = T^* \times 1000 / (\varphi f_y) = 5870.27 \times 1000 / (0.85 \times 500) =$

Calculation item	Result
ULS tension T*	5870.27 kN
Force basis	Offset physical tie force
Minimum tie width	823.7 mm
fy	500 MPa
φ	0.85
Required Ast	13812 mm²
Area of N28	616 mm²
Exact bars required	22.43
Adopt	23N28
Provided Ast	14162 mm²
Tie capacity	6019.0 kN
Utilisation	97.5%

AS 3600:2018: Tie reinforcement must be fully developed past the nodal zone so that the required design tie force is properly anchored at the node.

Tie S17

N7 → N8

Frozen nodal face centres

PASS

21N28 · Ast,prov 12931 mm²

Frozen nodal face centres

$A_{st,req} = T^* \times 1000 / (\varphi f_y) = 5424.34 \times 1000 / (0.85 \times 500) =$

Calculation item	Result
ULS tension T*	5424.34 kN
Force basis	Offset physical tie force
Minimum tie width	605.4 mm
fy	500 MPa
φ	0.85
Required Ast	12763 mm²
Area of N28	616 mm²
Exact bars required	20.73
Adopt	21N28
Provided Ast	12931 mm²
Tie capacity	5495.6 kN
Utilisation	98.7%

AS 3600:2018: Tie reinforcement must be fully developed past the nodal zone so that the required design tie force is properly anchored at the node.

Tie S9

N10 → N11

Frozen nodal face centres

PASS

15N28 · Ast,prov 9236 mm²

Frozen nodal face centres

$A_{st,req} = T^* \times 1000 / (\varphi\, f_y) = 3849.43 \times 1000 / (0.85 \times 500) =$

Calculation item	Result
ULS tension T*	3849.43 kN
Force basis	Offset physical tie force
Minimum tie width	654.9 mm
fy	500 MPa
φ	0.85
Required Ast	9057 mm²
Area of N28	616 mm²
Exact bars required	14.71
Adopt	15N28
Provided Ast	9236 mm²
Tie capacity	3925.4 kN
Utilisation	98.1%

AS 3600:2018: Tie reinforcement must be fully developed past the nodal zone so that the required design tie force is properly anchored at the node.

Tie S13

N7 → N11

Frozen nodal face centres

PASS

19N28 · Ast,prov 11699 mm²

Frozen nodal face centres

$A_{st,req} = T^* \times 1000 / (\varphi\, f_y) = 4961.63 \times 1000 / (0.85 \times 500) =$

Calculation item	Result
ULS tension T*	4961.63 kN
Force basis	Offset physical tie force
Minimum tie width	689.2 mm
fy	500 MPa
φ	0.85
Required Ast	11674 mm²
Area of N28	616 mm²
Exact bars required	18.96
Adopt	19N28
Provided Ast	11699 mm²
Tie capacity	4972.2 kN
Utilisation	99.8%

AS 3600:2018: Tie reinforcement must be fully developed past the nodal zone so that the required design tie force is properly anchored at the node.

Tie S15

N8 → N5
Frozen nodal face centres

PASS

2N28 · Ast,prov 1232 mm²

Frozen nodal face centres

$A_{st,req} = T^{*} \times 1000 / (\varphi\, f_y) = 268.68 \times 1000 \,/\, (0.85 \times 500) =$

Calculation item	Result
ULS tension T*	268.68 kN
Force basis	Offset physical tie force
Minimum tie width	1138.9 mm
fy	500 MPa
φ	0.85
Required Ast	632 mm²
Area of N28	616 mm²
Exact bars required	1.03
Adopt	2N28
Provided Ast	1232 mm²
Tie capacity	523.4 kN
Utilisation	51.3%

> **AS 3600:2018:** Tie reinforcement must be fully developed past the nodal zone so that the required design tie force is properly anchored at the node.

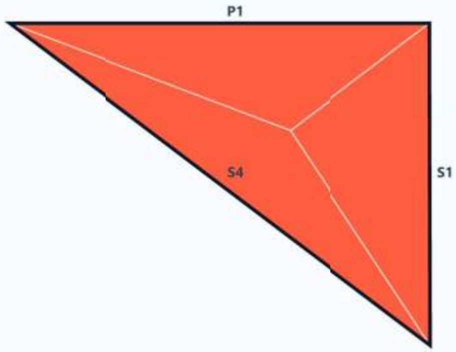
7. Nodal Zone Calculations

Node N5

Frozen · current
3 faces · graphical-edit

PASS

Local CST stress field · compression $-\sigma_2$
0 to 9.51 MPa



AS 3600 nodal strength check · Cl. 7.4.2

$\sigma_{c,p} = \quad \leq \quad \sigma_{allow} = \quad \rightarrow$

Design check item	Result
Node type	CCT · automatic
Faces / tension ties	3 / 1
φst	0.65
βn	0.80
f'c	65.0 MPa
Limit basis	φst × βn × 0.9f'c = 0.65 × 0.80 × 0.9 × 65.0
Governing face	S1
Governing principal compression σc,p	9.492 MPa
Allowable nodal compression	30.420 MPa
Utilisation	31.2%
Nodal strength result	PASS

Whole-node average stress tensor

$$\bar{\sigma} = [\,-9.491 \;\; -0.040\,;\; -0.040 \;\; -5.373\,]\ \text{MPa}$$

Stress result	Value
Polygon area	551611.2 mm²
Thickness	600.0 mm
Equilibrium residual	0.0000 kN
σx	-9.491 MPa
σy	-5.373 MPa
τxy	-0.040 MPa
Principal σ1	-5.373 MPa
Principal σ2	-9.491 MPa
Principal angle	-89.44°
Maximum shear	2.059 MPa
Compatibility class	near-uniform
Max traction mismatch	0.8%
RMS traction mismatch	0.6%
Local max compression	9.505 MPa
Local max tension	0.000 MPa
Local max τ	2.122 MPa

Boundary face stresses

Face	Type	Force	Width	σn signed	τ signed	σc,p	Mismatch
P1	load	3868.68 kN	1200.0 mm	-5.373 MPa	-0.001 MPa	5.373 MPa	0.8%
S4	member	6539.59 kN	1513.3 mm	-6.932 MPa	1.956 MPa	7.446 MPa	0.6%
S1	member	5235.50 kN	919.4 mm	-9.491 MPa	-0.072 MPa	9.492 MPa	0.4%

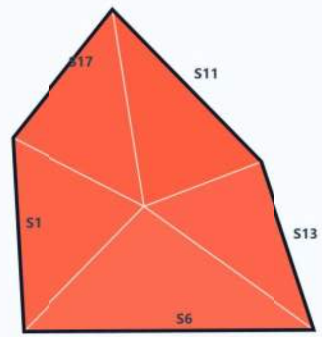
> **Local field:** Elastic equilibrium reconstruction using a centroid-fan CST mesh. Not a nonlinear cracked-concrete solution.
> • The boundary resultants contain a non-negligible resultant couple; the raw average stress tensor is not perfectly symmetric.

Node N7

Frozen · current
5 faces · graphical-edit

PASS

Local CST stress field · compression $-\sigma_2$
0 to 13.47 MPa



AS 3600 nodal strength check · Cl. 7.4.2

$\sigma_{c,p} = \quad \leq \quad \sigma_{allow} = \quad \rightarrow$

Design check item	Result
Node type	Complex 5-face node · manual limit
Faces / tension ties	5 / 4
φst	0.65
βn	—
f'c	—
Limit basis	Designer-entered allowable nodal compressive stress
Governing face	S17
Governing principal compression σc,p	14.276 MPa
Allowable nodal compression	30.000 MPa
Utilisation	47.6%
Nodal strength result	PASS

Whole-node average stress tensor

$$\bar{\sigma} = [\,-12.696 \quad 1.047\,; \quad 1.047 \quad -10.442\,]\ \mathrm{MPa}$$

Stress result	Value
Polygon area	994385.9 mm²
Thickness	600.0 mm
Equilibrium residual	0.0000 kN
σx	-12.696 MPa
σy	-10.442 MPa
τxy	1.047 MPa
Principal σ1	-10.030 MPa
Principal σ2	-13.107 MPa
Principal angle	68.54°
Maximum shear	1.538 MPa
Compatibility class	non-uniform
Max traction mismatch	19.0%
RMS traction mismatch	14.1%
Local max compression	13.468 MPa
Local max tension	0.000 MPa
Local max τ	2.829 MPa

Boundary face stresses

Face	Type	Force	Width	σn signed	τ signed	σc,p	Mismatch
S13	member	4963.07 kN	689.2 mm	-11.402 MPa	3.746 MPa	12.523 MPa	19.0%
S11	member	5873.24 kN	823.7 mm	-11.748 MPa	1.790 MPa	12.015 MPa	11.3%
S17	member	5424.37 kN	635.2 mm	-14.189 MPa	-1.117 MPa	14.276 MPa	9.6%
S1	member	5235.50 kN	755.2 mm	-11.543 MPa	0.523 MPa	11.567 MPa	10.5%
S6	member	6340.01 kN	1136.7 mm	-9.296 MPa	0.050 MPa	9.296 MPa	17.3%

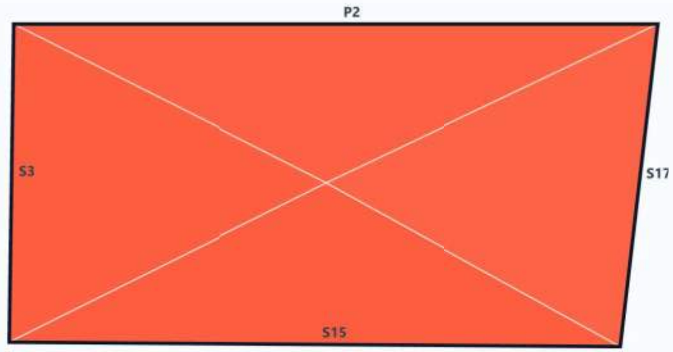
> **Local field:** Elastic equilibrium reconstruction using a centroid-fan CST mesh. Not a nonlinear cracked-concrete solution.
> • The boundary resultants contain a non-negligible resultant couple; the raw average stress tensor is not perfectly symmetric.

Node N8

Frozen · current
4 faces · graphical-edit

PASS

Local CST stress field · compression −σ₂
0 to 12.82 MPa



AS 3600 nodal strength check · Cl. 7.4.2

$\sigma_{c,p} = \quad \leq \quad \sigma_{allow} = \quad \rightarrow$

Design check item	Result
Node type	Complex 4-face node · manual limit
Faces / tension ties	4 / 2
φst	0.65
βn	—
f'c	—
Limit basis	Designer-entered allowable nodal compressive stress
Governing face	S17
Governing principal compression σc,p	16.152 MPa
Allowable nodal compression	30.000 MPa
Utilisation	53.8%
Nodal strength result	PASS

Whole-node average stress tensor

$$\bar{\sigma} = [\,-12.601 \;\; 1.798\,; \;\; 1.798 \;\; -2.769\,]\ \text{MPa}$$

Stress result	Value
Polygon area	698703.3 mm²
Thickness	600.0 mm
Equilibrium residual	0.0000 kN
σx	-12.601 MPa
σy	-2.769 MPa
τxy	1.798 MPa
Principal σ1	-2.451 MPa
Principal σ2	-12.920 MPa
Principal angle	79.96°
Maximum shear	5.235 MPa
Compatibility class	strongly-non-uniform
Max traction mismatch	705.5%
RMS traction mismatch	354.7%
Local max compression	12.819 MPa
Local max tension	0.000 MPa
Local max τ	5.939 MPa

Boundary face stresses

Face	Type	Force	Width	σn signed	τ signed	σc,p	Mismatch
P2	load	3600.00 kN	1200.0 mm	-5.000 MPa	0.000 MPa	5.000 MPa	57.3%
S3	member	4529.78 kN	593.3 mm	-12.677 MPa	-1.100 MPa	12.772 MPa	21.7%
S15	member	268.68 kN	1138.9 mm	-0.393 MPa	-0.004 MPa	0.393 MPa	705.5%
S17	member	5424.37 kN	605.4 mm	-13.302 MPa	6.785 MPa	16.152 MPa	41.3%

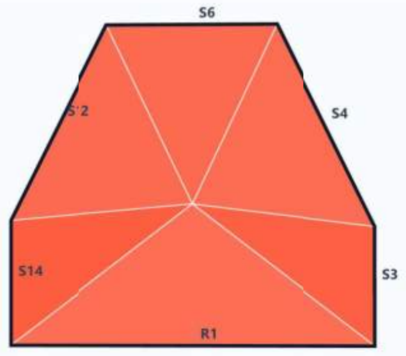
> **Local field:** Elastic equilibrium reconstruction using a centroid-fan CST mesh. Not a nonlinear cracked-concrete solution.
> • The boundary resultants contain a non-negligible resultant couple; the raw average stress tensor is not perfectly symmetric.

Node N9

Frozen · current
6 faces · graphical-edit

PASS

Local CST stress field · compression $-\sigma_2$
0 to 17.06 MPa



AS 3600 nodal strength check · Cl. 7.4.2

$\sigma_{c,p} = \quad \leq \quad \sigma_{allow} = \quad \rightarrow$

Design check item	Result
Node type	Complex 6-face node · manual limit
Faces / tension ties	6 / 0
φst	0.65
βn	—
f'c	—
Limit basis	Designer-entered allowable nodal compressive stress
Governing face	R1
Governing principal compression σc,p	16.410 MPa
Allowable nodal compression	30.000 MPa
Utilisation	54.7%
Nodal strength result	PASS

Whole-node average stress tensor

$$\bar{\sigma} = [\, -12.707 \;\; -0.021 \,; \;\; -0.021 \;\; -15.787 \,] \text{ MPa}$$

Stress result	Value
Polygon area	1648260.8 mm²
Thickness	600.0 mm
Equilibrium residual	0.0000 kN
σx	-12.707 MPa
σy	-15.787 MPa
τxy	-0.021 MPa
Principal σ1	-12.706 MPa
Principal σ2	-15.787 MPa
Principal angle	-0.39°
Maximum shear	1.540 MPa
Compatibility class	non-uniform
Max traction mismatch	19.6%
RMS traction mismatch	15.2%
Local max compression	17.058 MPa
Local max tension	0.000 MPa
Local max τ	2.811 MPa

Boundary face stresses

Face	Type	Force	Width	σn signed	τ signed	σc,p	Mismatch
S3	member	4529.78 kN	491.2 mm	-15.333 MPa	-1.066 MPa	15.407 MPa	18.4%
S4	member	6539.59 kN	925.8 mm	-11.567 MPa	-2.195 MPa	11.970 MPa	17.0%
S6	member	6340.01 kN	694.4 mm	-15.217 MPa	0.081 MPa	15.218 MPa	3.8%
S12	member	6284.92 kN	895.6 mm	-11.455 MPa	2.363 MPa	11.923 MPa	18.6%
S14	member	4805.60 kN	512.5 mm	-15.595 MPa	1.020 MPa	15.661 MPa	19.6%
R1	support	14768.93 kN	1500.0 mm	-16.410 MPa	-0.037 MPa	16.410 MPa	3.8%

> **Local field:** Elastic equilibrium reconstruction using a centroid-fan CST mesh. Not a nonlinear cracked-concrete solution.
> • The boundary resultants contain a non-negligible resultant couple; the raw average stress tensor is not perfectly symmetric.

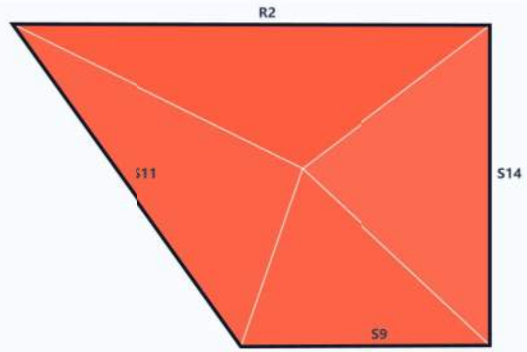
Node N10

Frozen · current PASS

4 faces · uniform-stress

Local CST stress field · compression −σ₂

0 to 8.71 MPa



AS 3600 nodal strength check · Cl. 7.4.2

$\sigma_{c,p} =$ $\leq$ $\sigma_{allow} =$ →

Design check item	Result
Node type	Complex 4-face node · manual limit
Faces / tension ties	4 / 2
φst	0.65
βn	—
f'c	—
Limit basis	Designer-entered allowable nodal compressive stress
Governing face	R2
Governing principal compression σc,p	8.410 MPa
Allowable nodal compression	30.000 MPa
Utilisation	28.0%
Nodal strength result	PASS

Whole-node averagestress tensor

$$\bar{\sigma} = [\,-7.924 \quad 0.204\,; \quad 0.204 \quad -8.339\,]\ \text{MPa}$$

Stress result	Value
Polygon area	1149615.7 mm²
Thickness	600.0 mm
Equilibrium residual	0.0000 kN
σx	-7.924 MPa
σy	-8.339 MPa
τxy	0.204 MPa
Principal σ1	-7.841 MPa
Principal σ2	-8.423 MPa
Principal angle	22.22°
Maximum shear	0.291 MPa
Compatibility class	near-uniform
Max traction mismatch	4.0%
RMS traction mismatch	3.0%
Local max compression	8.706 MPa
Local max tension	0.000 MPa
Local max τ	0.512 MPa

Boundary face stresses

Face	Type	Force	Width	σn signed	τ signed	σc,p	Mismatch
S14	member	4805.60 kN	1004.0 mm	-7.961 MPa	0.521 MPa	7.995 MPa	4.0%
R2	support	7568.93 kN	1500.0 mm	-8.410 MPa	-0.019 MPa	8.410 MPa	2.4%
S11	member	5873.24 kN	1239.6 mm	-7.897 MPa	-0.006 MPa	7.897 MPa	1.6%
S9	member	3851.86 kN	782.5 mm	-8.204 MPa	0.055 MPa	8.205 MPa	3.6%

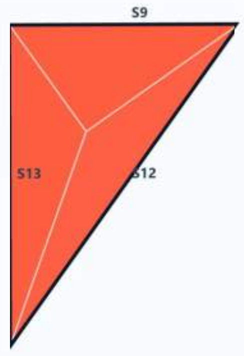
> **Local field:** Elastic equilibrium reconstruction using a centroid-fan CST mesh. Not a nonlinear cracked-concrete solution.
> • The boundary resultants contain a non-negligible resultant couple; the raw average stress tensor is not perfectly symmetric.

Node N11

Frozen · current
3 faces · uniform-stress

PASS

Local CST stress field · compression $-\sigma_2$
0 to 9.96 MPa



AS 3600 nodal strength check · Cl. 7.4.2

$\sigma_{c,p} = \quad \leq \quad \sigma_{allow} = \quad \rightarrow$

Design check item	Result
Node type	CTT · automatic
Faces / tension ties	3 / 2
φst	0.65
βn	0.60
f'c	65.0 MPa
Limit basis	φst × βn × 0.9f'c = 0.65 × 0.60 × 0.9 × 65.0
Governing face	S9
Governing principal compression σc,p	9.803 MPa
Allowable nodal compression	22.815 MPa
Utilisation	43.0%
Nodal strength result	PASS

Whole-node averagestress tensor

$$\bar{\sigma} = [\,-8.944 \;\; -0.004\,;\;\; -0.004 \;\; -9.802\,]\ \text{MPa}$$

Stress result	Value
Polygon area	302831.2 mm²
Thickness	600.0 mm
Equilibrium residual	0.0000 kN
σx	-8.944 MPa
σy	-9.802 MPa
τxy	-0.004 MPa
Principal σ1	-8.944 MPa
Principal σ2	-9.802 MPa
Principal angle	-0.24°
Maximum shear	0.429 MPa
Compatibility class	near-uniform
Max traction mismatch	0.7%
RMS traction mismatch	0.6%
Local max compression	9.962 MPa
Local max tension	0.000 MPa
Local max τ	0.504 MPa

Boundary face stresses

Face	Type	Force	Width	σn signed	τ signed	σc,p	Mismatch
S9	member	3851.86 kN	654.9 mm	-9.802 MPa	0.066 MPa	9.803 MPa	0.6%
S13	member	4963.07 kN	924.8 mm	-8.944 MPa	0.053 MPa	8.945 MPa	0.7%
S12	member	6284.92 kN	1134.1 mm	-9.225 MPa	0.461 MPa	9.248 MPa	0.6%

Local field: Elastic equilibrium reconstruction using a centroid-fan CST mesh. Not a nonlinear cracked-concrete solution.
• The boundary resultants contain a non-negligible resultant couple; the raw average stress tensor is not perfectly symmetric.

8. Calculation Notes

Strut checks report the AS 3600 compression-field type, βs, governing strut/tie angle, the Clause 7.1(g) 30° minimum angle check, and the stress limit φst βs 0.9f′c. The physical offset force is used where finite nodal geometry is available.
For bottle-shaped struts, Clause 7.2.4 bursting actions, divergence envelopes and the two-direction transverse reinforcement check are reported. Ax and Ay are total X- and Y-direction reinforcement areas crossing the bursting zone and act together through Ax sinγx + Ay sinγy. Separate ULS and SLS capacities, utilisations and PASS/FAIL results are shown.
Tie reinforcement uses Ast,req = T* / (φ fy), with the adopted bar quantity rounded up to the next whole bar. In accordance with AS 3600:2018, the adopted tie reinforcement must be fully developed past the nodal zone so that the required design tie force is properly anchored at the node.
Automatic three-face node limits apply to CCC, CCT and CTT nodes. A TTT node has no automatic CCC/CCT/CTT limit in STM Studio and therefore retains the designer-entered manual allowable stress, as do other non-standard/complex nodes.
Nodal demand is the governing principal compressive stress on the boundary faces. Whole-node average Cauchy tensor and local elastic centroid-fan CST results are also reported for stress-field review; the local heat map is not a nonlinear cracked-concrete solution.
Frozen node geometry is designer-approved geometry. A CHECK status is retained for stale nodes, unfrozen nodes, pending protected calculations or incomplete design checks.