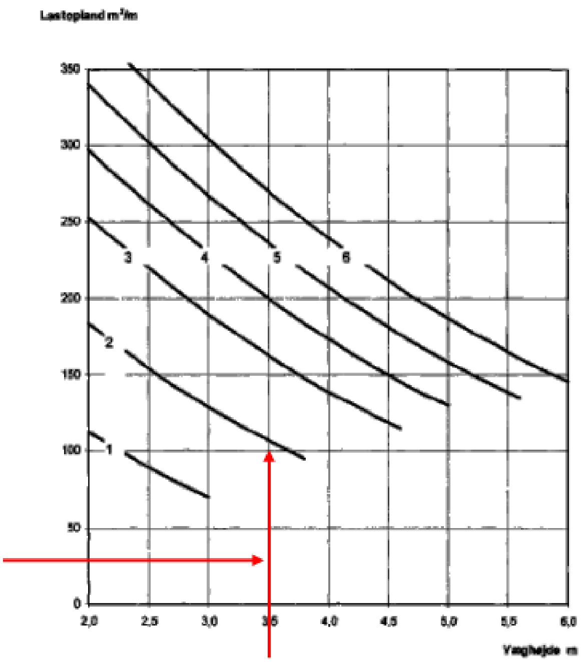
Structural analysis

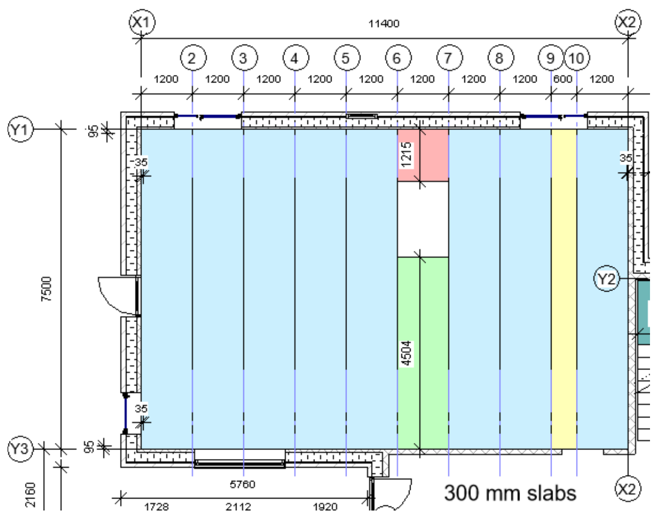
Load-bearing structures

1. Inner leaf – Dimensioning

3 story building
Wall height – 3100 mm

Tributary area calculation:
Span of slab= appx. 7,5m2 (half 3,75m2)
3 storeys= 3 x 3,75=11,25m2
Number of walls stacked: 2 x 3,1 = 6,2m2
Total: 11,25 + 6,2 = 17,45 m2





Min. wall thickness 150 mm.

> With particularly careful assembly and checking of the tolerances, it is possible to design with 65 mm compensation of 150 mm walls or beams. However, this only applies to elements with l ≤ 7.2 m.
> For lengths greater than 7.2 m, it is recommended to increase the compensation depth, or otherwise take into account the larger tolerance on the element length.

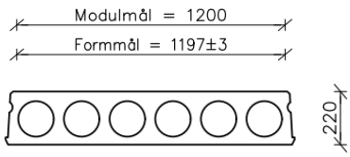
2. Deck element – Dimensioning

Self-weight of deck and on slab :

Komponent	Tykkelse [m]	Bredde [m]	Densitet kN/m3	Load kN/m2	Kommentar
Laminate	0,09	1	8,83	0,79	
Underlay	0,003	1	0,35	0,00	
Concrete	0,09	1	24	2,16	
Isolering	0,1	1	0,95	0,10	
Huldæk				2,90	Spæncon
				5,95	Total

Thickness of deck element – 220 mm

EX22



Self-weight

Self-weight on the slab: 3,05 kN/m^2

Imposed load

Main category: B

Sub category: B

Offices and light industry.

Imposed load from people/furniture: 2,50 kN/m2

Line load from moveable partitions: ≤ 2 kN/m

Uniform load from moveable partitions: 0,80 kN/m2

Design load

qEd = 1,0*3,17 + 1,5*(2,50 + 0,80) = 8,12 kN/m2

Crack load

qErev = 3,17 + (2,50 + 0,80) = 6,47 kN/m2

Balance load

qEbal = 3,17 kN/m2

Chose element: ElementEX22

Span (visible width): 7800 mm

Chose reinforcement: 8 L12,5

Ultimate Limit States (ULS)

qRd = 18,20 kN/m2 ≥ qEd = 8,12 kN/m2 Load bearing capacity OK!

Cracking (rev)

qrev = 12,50 kN/m2 ≥ qErev = 6,47 kN/m2 No cracking. OK!

Deflection (bal)

qbal = 3,80 kN/m2 ≥ qEbal = 3,17 kN/m2 Deflection OK!

Element data		
Height:	220	mm
Reinforcement:	8 L12,5	(L = lines)
Self-weight slab:	3,10	kN/m^2

Ultimate Limit States (ULS) - included self-weight of the slab

Ed = 1,0*(3,17 + 3,10) + 1,5*(2,50 + 0,80) = 11,22 kN/m2

Serviceability Limit States (SLS) - included self-weight of the slab

Ed = (3,17 + 3,10) + 0,4*(2,50 + 0,80) = 7,59 kN/m2

		Spændvidde		4,2	4,8	5,4	6,0	6,6	7,2	7,8
6 L9,3 + 2 L12,5	M_{Rd}	141,50 kNm	q_{Rd}	-	-	29,1	**23,0**	**18,4**	**15,0**	**12,3**
	V_{Rd}	102,15 kN	q_{vRd}	-	-	**28,3**	25,1	22,6	20,4	18,6
	M_{mREI60}	110,84 kNm	q_{mREI60}	-	-	22,1	17,3	13,7	11,0	8,9
	V_{vREI60}	55,10 kN	q_{vREI60}	-	-	**13,8**	**12,1**	**10,7**	**9,5**	**8,5**
	$M_{mREI120}$	53,42 kNm	$q_{mREI120}$	-	-	9,0	6,7	4,9	3,6	2,6
	$M_{mREI120}$ *	95,43 kNm	$q_{mREI120}$ *	-	-	18,6	14,4	11,4	9,0	7,2
	$V_{vREI120}$	47,15 kN	$q_{vREI120}$	-	-	11,3	9,9	8,7	7,7	6,8
	M_{rev}	111,52 kNm	q_{rev}	-	-	22,3	17,4	13,8	11,1	9,0
	M_{bal}	43,86 kNm	q_{bal}	-	-	6,8	4,9	3,5	2,4	1,6
	f_{lev} i mm		f_{lev}	-	-	7,9	8,8	9,2	9,2	8,5
	f_{e1} i mm		f_{e1}	-	-	0,5	0,8	1,1	1,6	2,2
	Egensvingning	Hz	$f_{,1}$	-	-	15	13	12	11	10

Table A1.4 DK NA Empirical values for acceptable natural frequencies and acceleration limits

Structure	Action	Normally satisfactory functioning	Often unsatisfactory functioning	Acceleration limit in % of the gravity acceleration
Grandstands, fitness centres, sports halls and public premises	Rhythmic load caused by movement of people	$n_e > 10$ Hz	$n_e < 6$ Hz	10 %
Residential buildings	Load from walking	$n_e > 8$ Hz	$n_e < 5$ Hz	0,1 %
Office premises	Load from walking	$n_e > 8$ Hz	$n_e < 5$ Hz	0,2 %
NOTE - Natural frequencies and accelerations are calculated during normal use, where the fluctuating action is typically considerably less than the action corresponding to the quasi-permanent combination specified in clause 6.5.3 of EN 1990.				

Table A1.4 from danish national annex to Eurocode 0

Overlap over load-bearing wall: 95 mm (min. 75 + 20 mm for tolerance)
Side: 35 mm

3. Foundation

Links min 10 mm placed every 300-400 mm

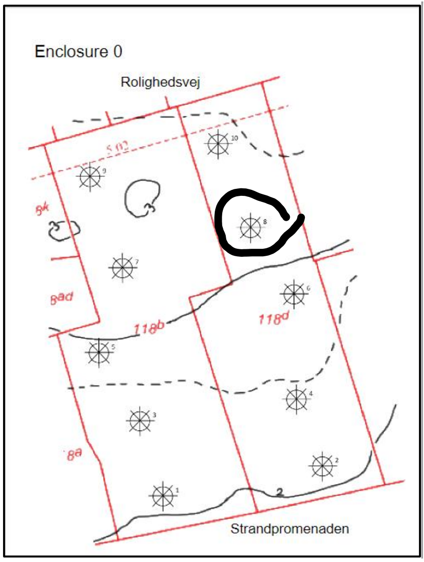
Perimeter reinforcement min. 12mm

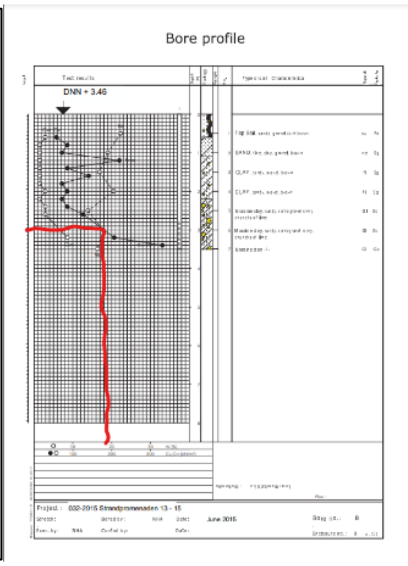
Vertical links 8mm

Partition walls – 200 mm (min 180 mm)

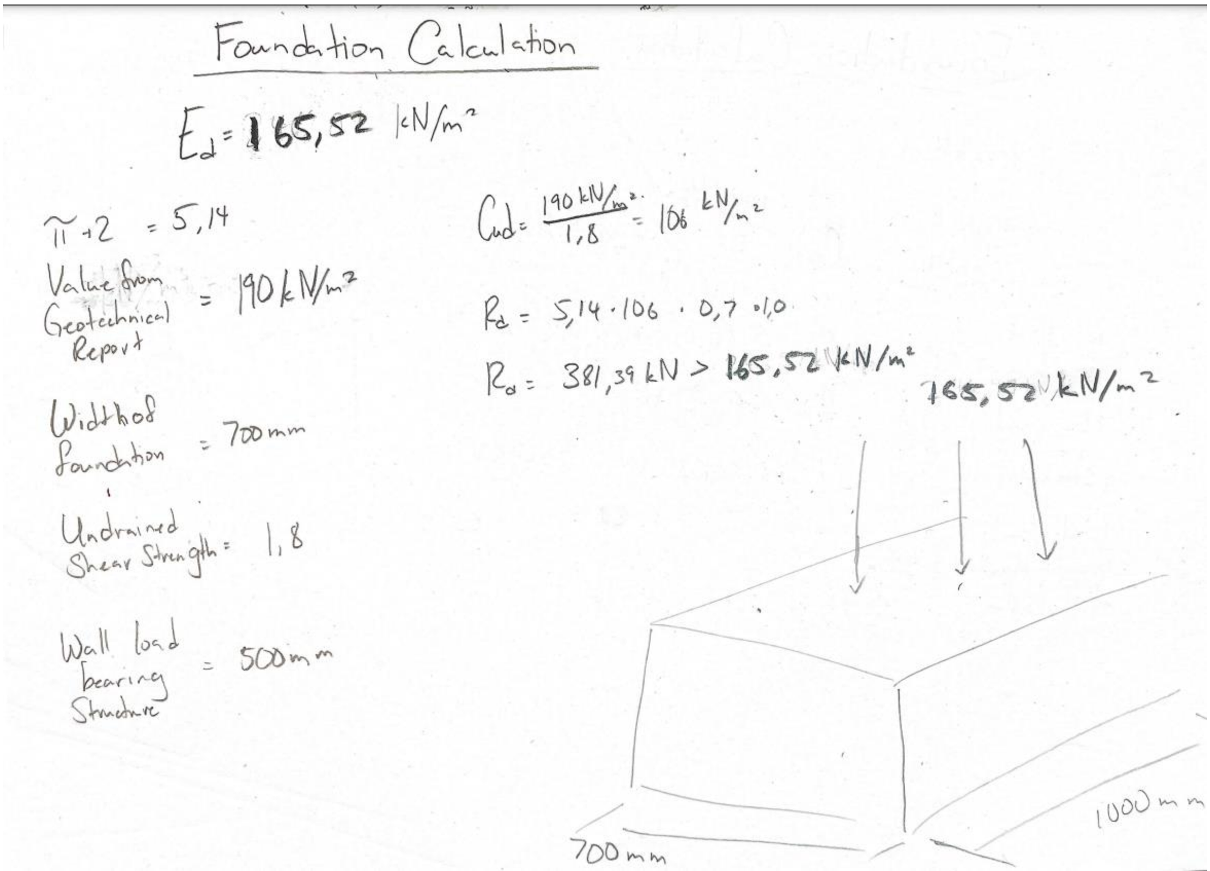
Foundation Calculation

To be able to figure out what the right size of the foundation can be. We must calculate if the foundation can withhold the weight that is on top of the foundation. To be able to calculate this, we must look at the geotechnical report that is provided to us. We were provided multiple results from our plot, but to be safe we chose the results that show area that can carry the load the least, which is result number 8. Calculations will be attached below:





Building component	Characteristic load				CC2		ψ_n	γ		Reduction factor for openings	Design load	Notes
	g [kN/m²]	q [kN/m²]	Tributary area span [m]	Load pr. meter [kN/m]	Consequense class factor	Category	Combination factor	Safety factor	Floor Reduction factor		Total load [kN/m]	
Dead load												
Roof	3,30		7,5	24,8	1,0		1	1,0		1,00	24,75	
Wall 2 floor	5,67		2,8	15,9	1,0		1	1,0		1,00	15,88	
Storey partition 2 floor	5,95		7,5	44,6	1,0		1	1,0		1,00	44,63	
Wall 1 floor	5,67		3,1	17,6	1,0		1	1,0		1,00	17,58	
Storey partition 1 floor	5,95		7,5	44,6	1,0		1	1,0		1,00	44,63	
Wall ground floor	5,67		3,1	17,6	1,0		1	1,0		1,00	17,58	
Storey partition ground floor	6,07		7,5	45,5	1,0		1	1,0		1,00	45,53	
Wall basement	11,83		2,8	33,1	1,0		1	1,0		1,00	33,12	
										ΣG_d =	140,85	
Imposed load												
Residence all floors		1,50	15,0	22,5	1,0	A	1	1,5	0,667		22,51	
Climatic loads												
Snow		0,80	6,0	4,8	1,0		0,3	1,5			2,16	
Wind		-1,20	6,0	-7,2	1,0		0,3	0			0,00	
										ΣS_d =	165,52	Total load pr. meter [kN/m]



Foundation Calculation

$E_d = 165,52$ kN/m²

$\pi + 2 = 5,14$

Value from Geotechnical Report $= 190$ kN/m²

Width of foundation $= 700$ mm

Undrained Shear Strength $= 1,8$

Wall load bearing Structure $= 500$ mm

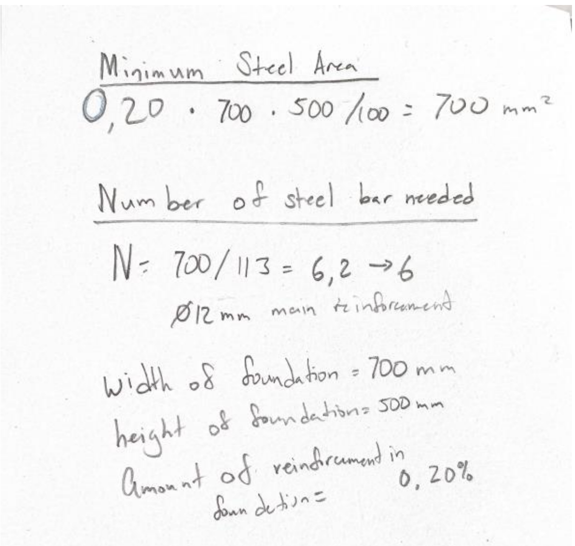
$C_{ud} = \frac{190 \text{ kN/m}^2}{1,8} = 106 \text{ kN/m}^2$

$R_d = 5,14 \cdot 106 \cdot 0,7 \cdot 1,0$

$R_d = 381,39 \text{ kN} > 165,52 \text{ kN/m}^2$

<u>Reinforcement</u>

We would need 12 mm diameter of main reinforcement and 8 mm diameter of stirrups. The minimal steel area is 700 mm^2. We would need 6 main reinforcements and stirrups will be placed every 1000 mm. Calculations will be attached below:



Minimum Steel Area

$0,20 \cdot 700 \cdot 500 / 100 = 700 \text{ mm}^2$

Number of steel bar needed

$N = 700 / 113 = 6,2 \rightarrow 6$

Ø12 mm main reinforcement

width of foundation = 700 mm

height of foundation = 500 mm

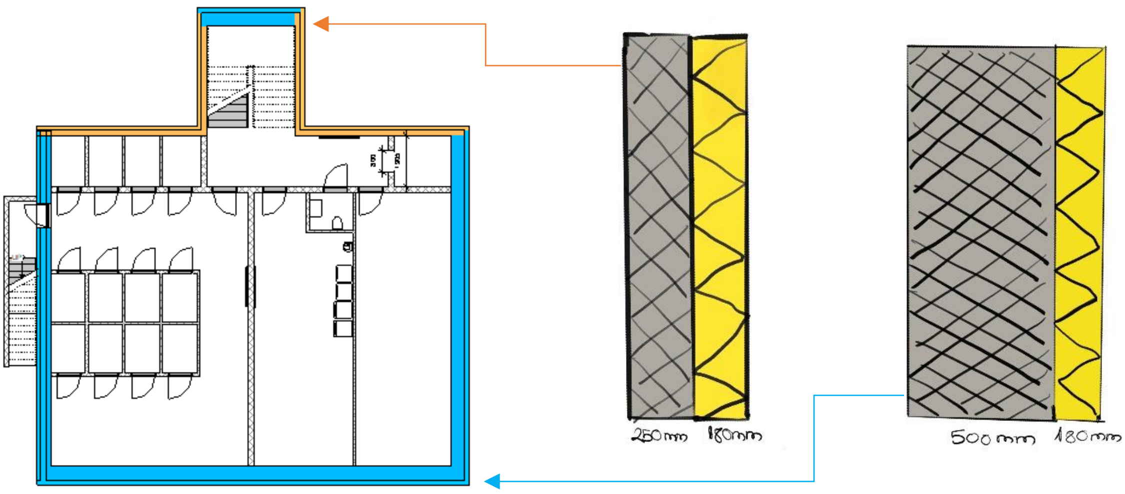
Amount of reinforcement in foundation = 0,20%

4. Basement external wall

Basement external wall made of in-situ casted concrete with external XPS insulation:

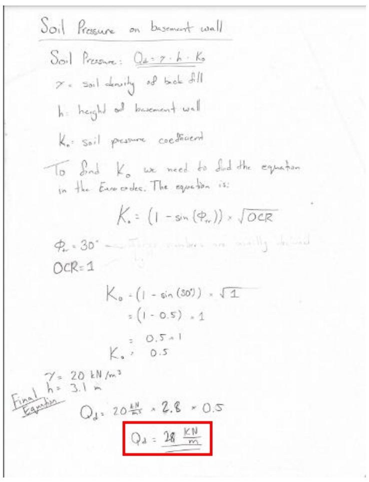
- The dimensions of the basement wall under an external wall are 500 mm + 180 mm insulation

- The dimensions of the basement wall under an internal load-bearing wall is 250 mm + 180 mm insulation



5. Soil Pressure Calculation

The soil pressure on our basement wall is 28 KN/m according to our calculations.



Soil Pressure on basement wall

Soil Pressure: $Q_d = \gamma \cdot h \cdot K_0$

γ = soil density of back fill

h = height of basement wall

K_0 = soil pressure coefficient

To find K_0 we need to find the equation in the Eurocodes. The equation is:

$$K_0 = (1 - \sin(\Phi_{tr})) \times \sqrt{OCR}$$

$\Phi_{tr} = 30°$

OCR = 1

$$K_0 = (1 - \sin(30°)) \times \sqrt{1} = (1 - 0.5) \times 1 = 0.5 \times 1$$

$K_0 = 0.5$

$\gamma = 20\ kN/m^3$

h = 3.1 m

Final Equation

$Q_d = 20 \frac{kN}{m^3} \times 2.8 \times 0.5$

$Q_d = 28 \frac{KN}{m}$

The soil/sand density used is 20 KN/m^3

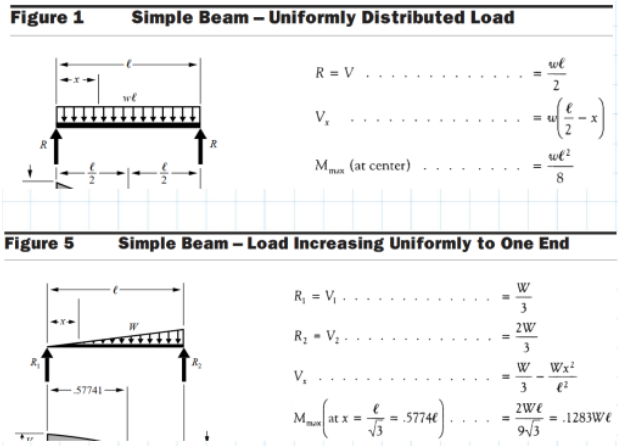
The height of our basement wall is 2,8 m

To find the soil pressure coefficient we used 30 degrees for the back fill type and the OCR as 1 due to it being a new building.

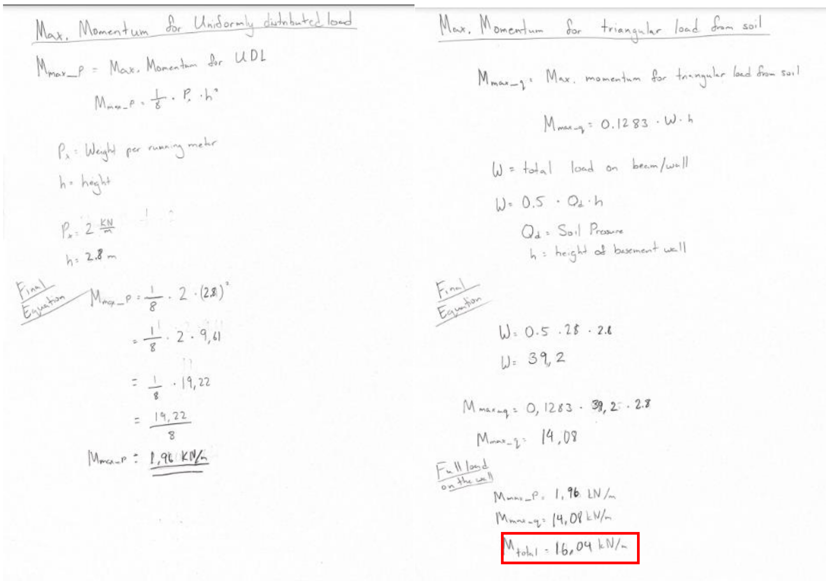
Total Momentum

To determine the minimum thickness of our basement wall and the maximum height, we must calculate the total momentum of the basement wall.

To find the total momentum we must first find the maximum momentum with uniformly distributed load and triangular load on the basement wall. We used the equations below to find these.



We first found the uniformly distributed load on the wall and what we ended up with is 2,40 KN/m. After finding this we calculated the triangular load on the wall. What we ended up with is 19,11 KN/m. To find the total we must add the two values together and in total we got 21,51 KN/m.



Basement Wall dimensions

We use these numbers to find the minimum thickness and maximum height of our basement walls. We take the value we got from the load scheme, which is 166,42 KN/m and the value from the soil pressure, which is 16,04 KN/m, and see where it intersects in the table below.

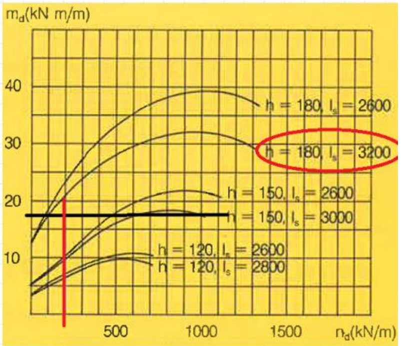


Fig 2. M-N diagram from Betonelementforeningen Bind 2

This table is from Betongelementforegningen bind 2. As seen on the table, it intersects where the line meets the curved line. The value associated with this curve is:

Thickness = min.180 mm

Height = max. 3200 mm

The load bearing structure of our basement walls have a thickness of 500 mm and height of 2800 mm as seen in our basement wall analysis.

Though we can go lower in thickness, we must have at least 500 mm thickness due to our external wall above the terrain having a thickness of 509 mm.