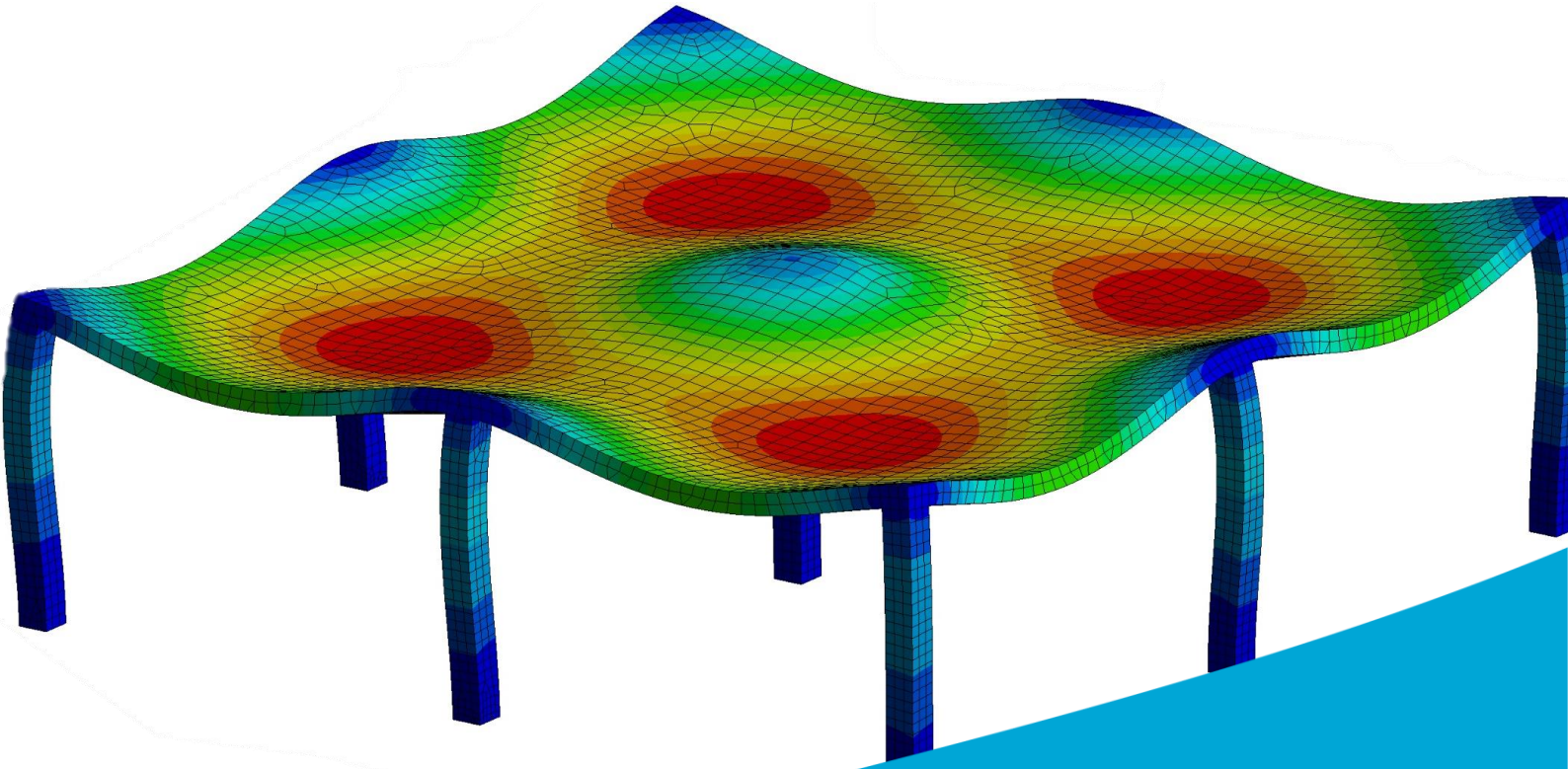

Finite Element Method

Accuracy of Floor Moments and Stresses Above Edge Columns

Author: Daniel Blanco Blanco
Date: 25th of June 2025

TU Delft

Finite element method

Accuracy of Floor Moments and Stresses Above Edge Columns

By

Daniel Blanco Blanco
5806704

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In partial fulfilment of the requirements for the degree of:
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Thesis committee: Dr.ir. P.C.J. Hoogenboom — TU Delft, supervisor 1
Ir. S. Pasterkamp — TU Delft, supervisor 2

TU Delft

Preface and Acknowledgements

This report was written as part of my bachelor thesis for the Civil Engineering programme at Delft University of Technology. The research explores the accuracy of 2D and 3D structural models, with a focus on the application of different plate theories. It has been both a challenging and rewarding project, through which I have gained a deep appreciation for the complexity of structural modelling. I hope that it provides valuable insights to readers and contributes to the field of civil engineering.

I would like to thank my two supervisors Pierre Hoogenboom and Sander Pasterkamp, for the feedback, guidance, and insightful conversations regarding the research.

Daniel Blanco Blanco
Delft, 17 June 2025

Summary

The most accurate representation of reality is achieved by making a 3D linear elastic model with volume elements using software such as ANSYS. However, ANSYS is not available for most structural engineers. Therefore, most structural engineers use 2D finite element software, such as SCIA Engineer, to model structures that are in reality three-dimensional. This raises the question of whether 2D models can accurately recreate all the 3D behaviours, especially in complex areas such as above edge columns. Differences in calculated bending moments and stresses may occur at edge columns due to the simplifications and assumptions in 2D analyses.
To make more realistic 2D models, structural engineers get creative. Some refine the element size, while others represent column supports using four springs.

To address the problem, the thesis poses one main research question and three sub-questions. The main research question is:

"Does the 2D model give the same moments and stresses as the 3D model? Is the deviation acceptable?"

The sub-questions guiding the investigation to the main research question are:

1. *"Do both the Kirchhoff and the Mindlin-Reissner plate theory yield results that align closely enough with the 3D model?"*
2. *"Is the use of four springs to model a column valid?"*
3. *"Is the use of a point support to model an edge column valid?"*
4. *"What is the optimal size for finite elements to ensure accuracy in the model?"*

In the situation modelled the span to thickness ratio is larger than five. According to J. Blaauwendraad when this is the case, the shear deformation is negligibly small and Kirchhoff plate theory should be used (Blaauwendraad, 2012). Based on this background, the structure was set up with stresses and moments calculated at a predetermined point for different element sizes across different configurations

In the 2D analysis, the supports from columns were represented in a "column model" and a "spring model". Additionally, a 3D model of the same floor was created in ANSYS. Mesh refinement is applied, the initial mesh has an average 2D element size of 400 mm, and this size is halved until a final element size of 25 mm. The 2D Model is analysed once with the Kirchhoff plate theory and once with Mindlin–Reissner plate theory. To validate the models, two specific measurements were used, and an acceptability limit of 10 percent difference from the 3D model was established.

The 2D model results were evaluated against the 3D model results. The comparison shows that the Mindlin–Reissner plate theory generally outperforms the Kirchhoff theory, especially in less accurate models. As the model becomes more accurate, the difference between the two theories becomes negligibly small. The use of springs significantly enhances accuracy, and although a mesh size equal to twice the plate thickness yields the most accurate results, further mesh refinement does not improve accuracy but instead increases result consistency.

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1 Introduction

1.1 Problem

2D finite element programs, such as SCIA Engineer or Axis VM, are used by structural engineers to make an accurate calculation of the moments and stresses in the floor. These small elements calculations are based on the Kirchhoff plate theory or the Mindlin-Reissner plate theory. Due to the limitations of these theories, the calculation approximates reality. A better description of reality is a linear elastic model with volume elements. This 3D calculation can be made with ANSYS. However, ANSYS is not available for most structural engineers. To make a more realistic calculation in 2D, support by a column is often modelled with four springs. The springs represent the corners of the rectangular column[1].

Calculating the correct moments is important for concrete structural engineers. They determine reinforcement based on moments. Calculating the correct stress is important for steel structural engineers. They evaluate their designs with the Von-Mises stress.

To address the problem, the thesis poses one main research question and two sub-questions. The main research question is:

"Does the 2D model give the same moments and stresses as the 3D model? Is the deviation acceptable?"

The sub-questions supporting the main research question are:

1. *"Do both the Kirchhoff and the Mindlin-Reissner plate theory yield results that align closely enough with the 3D model?"*
2. *"Is the use of four springs to model a column valid?"*
3. *"Is the use of a point support to model an edge column valid?"*
4. *"What is the optimal size for finite elements to ensure accuracy in the model?"*

1.2 Approach

The structure of the report is as follows. In chapter 2, a literature review was conducted to examine plate theories and the principles of finite element analysis. Chapter 3 outlines the methodology, explaining the model setup. SCIA Engineer and ANSYS are installed and studied, with stresses and moments calculated at a predetermined point for different element sizes in each model. Additionally, in SCIA Engineer, calculations are performed for both the Kirchhoff and Mindlin-Reissner plate theories. Chapter 4 focuses on the validation of the models, and Chapter 5 presents the results. Finally, a conclusion to the research question is formed in Chapter 6 and Chapter 7 makes some observations for improvement in the methodology used in this report and opportunities for future research.

[1] Personal communication with P.C.J. Hoogenboom

2 Literature Research

This chapter explains the theoretical background needed to understand plate theory and finite element modelling. It clarifies when to use different plate theories and why shear deformation matters. The chapter also outlines how the Finite Element Method works and what affects its accuracy. It highlights the importance of mesh refinement and singularities.

2.1 Plates

In many construction projects concrete plates get applied. According to J. Blaauwendraad a plate is a collective term for systems in which transfer of forces occur in two directions. If it only spans in one direction it would be called a beam. In practice, plates are used in walls, floors, bridges, and roofs (Blaauwendraad, 2012). If the plate is made of concrete, it is called a slab.
Plates can be subdivided into two types: loaded perpendicularly to their plane and loaded in their plane called membrane state or disk. When a plate is loaded perpendicular to the plate, it is expected that the plate will undergo deflections, moments, and shear forces. This report focuses on floors. Floors are plates loaded perpendicular to their plane.

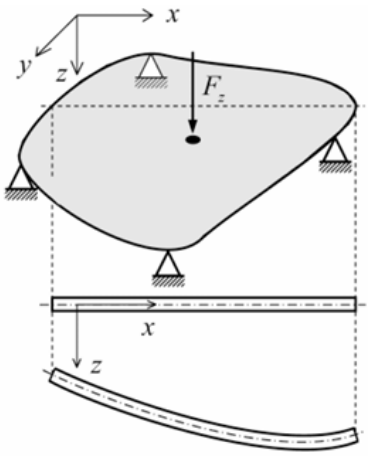

Figure 2.1: Plate with transverse load (Blaauwendraad, 2012)

To predict the behaviour of plates under loading several different theoretical models have been created. For these different theoretical models, we must distinguish between thick and thin plates, although there are theories that apply for both.

2.1.1 Kirchhoff Plate Theory

This subchapter is dedicated to the Kirchhoff plate theory in Cartesian coordinates. It is common practice to refer to the Kirchhoff plate theory as the thin plate theory. Kirchhoff should only be used for plates where the span to thickness ratio is larger than 5 (Blaauwendraad, 2012). When this is the case the shear deformation is negligibly small, we then speak of a so-called shear-rigid plate.

An assumption that needs to be made in the Kirchhoff plate theory is that the plates must be of homogeneous and orthotropic material. There are many assumptions in this plate theory but in this report only the main one will be discussed.

Although shear is negligibly small, there still is bending and stress on the plate due to the perpendicular load. The bending moment is obtained by integrating the axial stress (Timoshenko, 1959).

$$m_{xx} = \int_{-t/2}^{t/2} \sigma_{xx} z \, dz \qquad m_{yy} = \int_{-t/2}^{t/2} \sigma_{yy} z \, dz \qquad m_{xy} = \int_{-t/2}^{t/2} \tau_{xy} z \, dz \qquad (2.1)$$

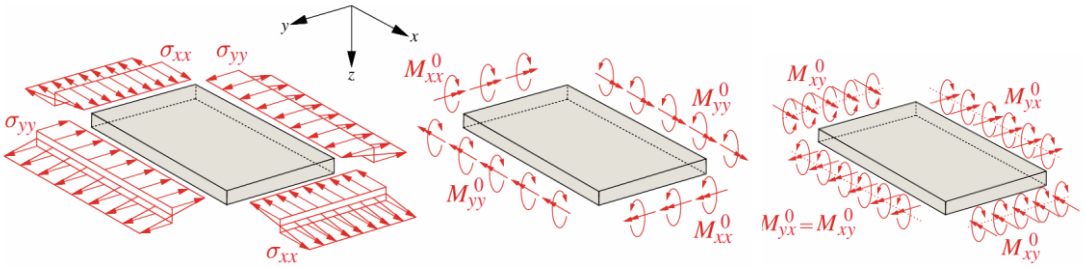

Figure 2.2: Normal stresses (left) and bending moments (middle and right) (Mittelstedt, 2022)

Simply Supported edge.

If a plate is simply supported along the edge, we get a deflection and a moment along the edge. Usually, the bending moment m_{xx} is zero at the edge. So, in practice two plate quantities at the simply supported edge are non-zero, the shear force v_x and the torsional moment m_{xy}. This raises a difficulty, because plate stress resultants must be balanced by one support reaction f, see Figure 2.4.

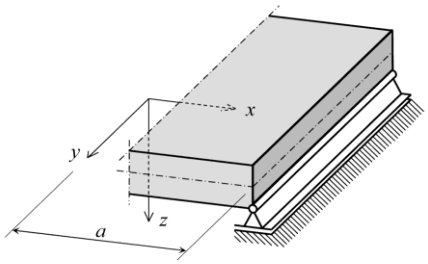

Figure 2.3: Simply supported edge (Blaauwendraad, 2012)

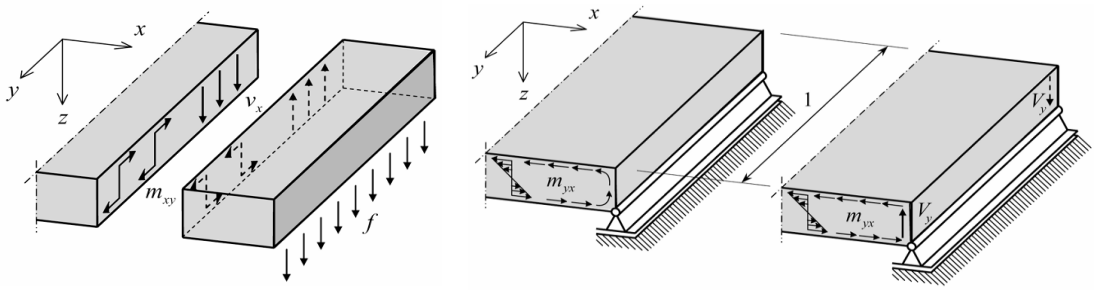

Figure 2.4: Support reaction (left) and constant twisting moment (right) edge (Blaauwendraad, 2012)

According to Blaauwendraad, twisting shear stresses cannot act on the edge of the plate. As a result, they must redirect around the ends, which occurs within a narrow edge zone whose length is approximately equal to the plate thickness. In this small region, the vertical component of the shear stresses results in a force V_y, which is interpreted in thin plate theory as a concentrated shear force in the y-direction at the edge (Blaauwendraad, 2012).
On a section located on the positive y-side, this force acts upwards, while on a section on the negative y-side, it acts downwards. Applying equilibrium (see Figure 2.5) leads to the following relation:

$$m_{xy} = \int_{-t/2}^{t/2} \tau_{xy} z \, dz = V_y \qquad (2.2)$$

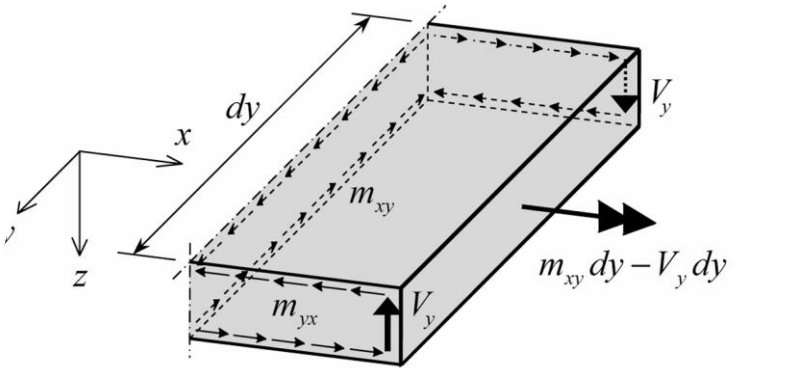

Figure 2.5: Determination of concentrated shear force at edge (Blaauwendraad, 2012)

2.1.2 Mindlin-Reissner Plate Theory

This subchapter focuses on the Mindlin–Reissner plate theory, also known as the First-Order Shear Deformation Theory (FSDT). This theory is applied to thick plates, which are defined as plates with a span-to-thickness ratio less than five. Unlike thin plate theory, where shear deformation is negligible, thick plate theory accounts for significant shear deformation (Blaauwendraad, 2012). As a result, shear forces become relevant. In Mindlin theory, these distributed shear forces are determined by integrating the shear stresses through the plate thickness.

$$v_y = \int_{-t/2}^{t/2} \tau_{yz}\, dz \qquad v_x = \int_{-t/2}^{t/2} \tau_{xz}\, dz \tag{2.3}$$

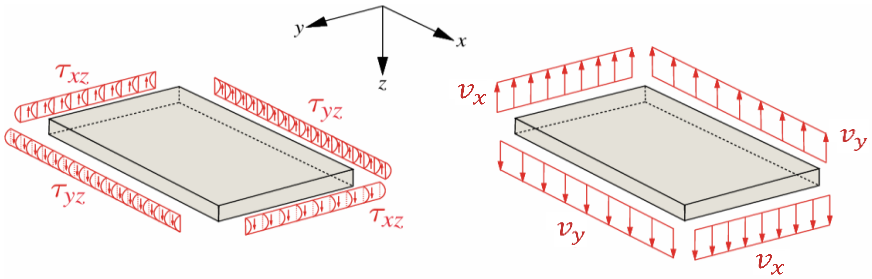

Figure 2.6: Transverse shear stresses (left) and transverse shear force flows (right) (Mittelstedt, 2022)

2.2 Finite Element Method

The Finite Element Method (FEM), is a computational tool in structural engineering which was a great improvement from its predecessor of the Finite Difference Method (FDM) (Blaauwendraad, 2012). The Finite Element Method is a numerical technique for analysing structures by discretising the entire body into a number of smaller elements. Constraints and loads are then applied to these elements, and the unknowns are solved based on the governing equations (Kundu, 2020). The use of this discretisation method is justified particularly when exact analytical solutions are not feasible, and when classical approximation methods reach their limitations (Blaauwendraad, 2012). The analysis is typically carried out using software.

2.2.1 Mesh Refinement

The first step in the Finite Element Method is to discretise the structure into a large number of elements. In this report, plane elements are used, meaning that the dimension in one direction is small compared to the other two. These elements are connected at nodes, located at the corners of each element (Blaauwendraad, 2012).

Like all finite elements, elements yield more accurate results when their size is small. But refining a mesh to half element size, requires approximately 4 times as many nodes, 16 times as much memory and computer hard disk space and 64 times as much computation time.
An experienced finite element analyst can often judge whether the mesh is sufficiently refined by visual inspection. However, when uncertainty remains, a standard mesh convergence procedure is followed:

1) Perform the analysis using an initial mesh.
2) Refine the mesh by halving the element size.
3) Compare the key results. If they do not change significantly, the mesh is considered sufficiently fine. If notable changes are observed, repeat the refinement process starting from step 2.

If there is a belief that sufficient accuracy has been achieved, the analysis can be considered complete. Then, it is also possible to estimate the result that would be obtained with an extremely fine mesh. This can be done by adding the difference between the last two results to the most recent result, providing an approximation of the exact value.
Also, the shape of the elements is important. Quadrilaterals are more accurate than triangles of the same order. Therefore, Quadrilaterals will be used in this report (Hoogenboom).

2.2.2 Singularities

A singularity in a linear elastic model is a point where forces or stresses become unrealistically large, theoretically approaching infinity. Common locations for singularities are at point loads, point supports, re-entrant corners, and abrupt changes in support conditions (Hoogenboom).
While singularities can be removed by refining the model with more realistic geometry or loading, doing so requires extra effort and computational cost. Therefore, engineers often leave singularities in the model and interpret the results carefully, disregarding unrealistic peaks and calculating actual stresses manually when needed (Hoogenboom).

2.2.3 Kirchhoff and Mindlin Reissner Theory

The choice of plate theory influences the results of the finite element method analyses. Traditionally, Kirchhoff theory has been used but nowadays Mindlin theory has become more common, especially for thick plates (Blaauwendraad, 2012).

In his book, J. Blaauwendraad analysed a simply supported square plate using both Kirchhoff and Mindlin theories, considering both thin and thick plate cases. The mesh can be seen in Figure 2.7.

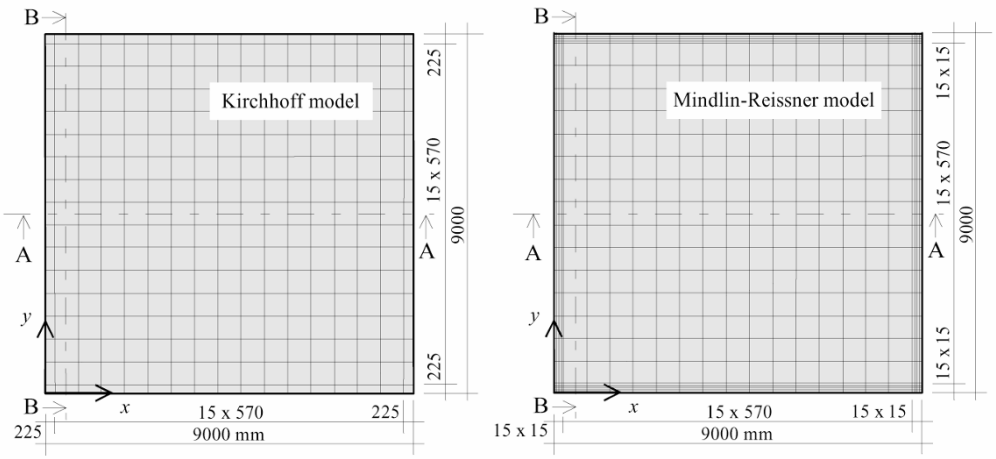

Figure 2.7: Mesh for plate analyses (Blaauwendraad, 2012)

The differences in displacement and moment between the two approaches were around 2%. A more significant difference appeared at the corners. Mindlin theory produced peaks, which did not appear in the Kirchhoff results, see Figure 2.8 (Blaauwendraad, 2012).

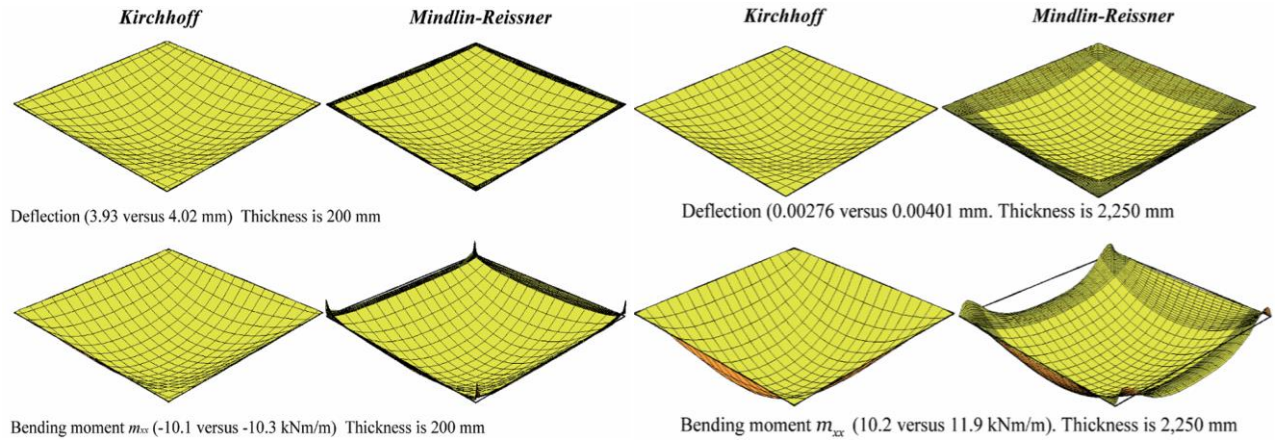

Figure 2.8: Deflection and bending moment (Blaauwendraad, 2012)

The Kirchhoff theory produces a twisting moment at the edge, while the Mindlin theory reduces it to nearly zero, but only in a narrow edge zone, see Figure 2.9. Despite this, Mindlin requires an impractically fine mesh and still shows less accurate results near the corners compared to Kirchhoff. When both theories are used using a practical mesh, Mindlin performs worse giving less accuracy. Therefore, Kirchhoff theory is recommended for thin plates, as it provides more accurate results.
With Kirchhoff elements, the mesh size needs to be bigger than the plate thickness (Blaauwendraad, 2012). It is recommended to use element widths and lengths of approximately twice the plate thickness, as smaller elements do not significantly affect the results.

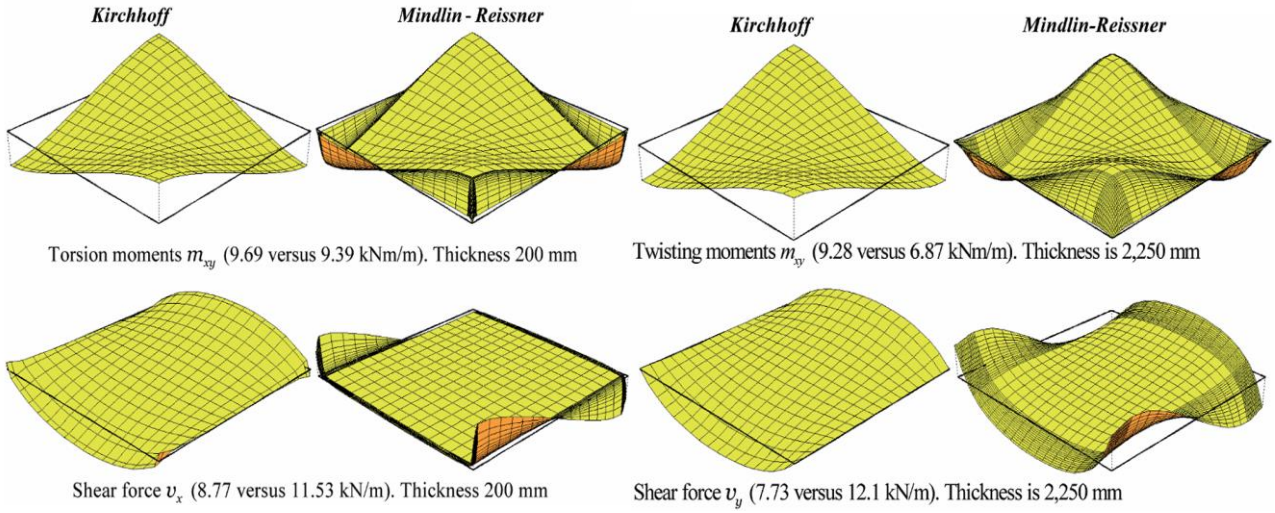

Figure 2.9: Twisting moment and shear force (Blaauwendraad, 2012)

For thick plates Mindlin theory is appropriate. In such cases, the mesh should be refined along the plate edges, within a zone approximately equal to the plate thickness. A resolution of five elements across this edge zone is considered sufficient (Blaauwendraad, 2012). Consequently, element widths at the edges should be approximately one tenth of the plate thickness.

3 Methodology

This chapter describes the structure being modelled and the reasoning behind its design. The chapter also shows the 2D column model, 2D spring model, and full 3D volume model used to compare results. The chapter also explains the methods used to evaluate stresses, bending moments, displacements, and reaction forces.

3.1 Model Description

For the structure that is going to be modelled, we consider a rectangular flat floor plate measuring ten metres by ten metres. The floor plate is made of concrete of class C30/37 and has a thickness of 200 mm. The floor is supported by edge columns located at the corners and at the midpoints of each side. There is also a column at the centre. Each column has a square cross-section with a width of 300 mm and a height of three metres. The columns have fixed supports at the base. The load on the structure will be its self-weight and an additional load of 10 kN/m^2.

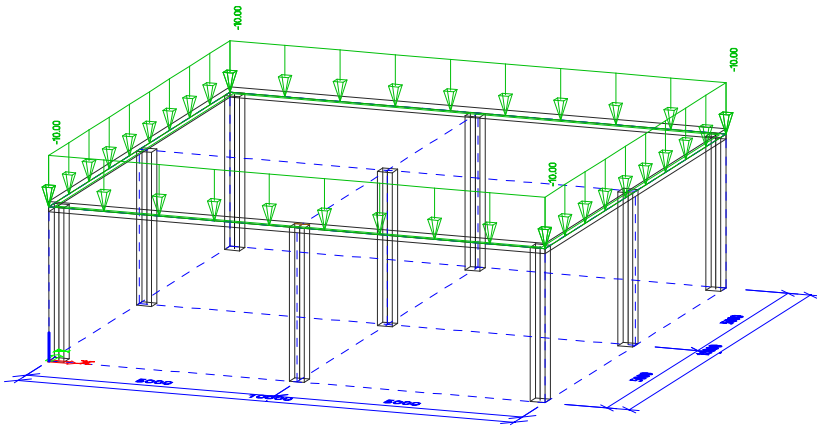

Figure 3.1: Structure modelled in SCIA.

For each model, the results analysed will be the moments and stresses in the plate at the point located at $x = 5m,\ y = 0.3m,\ z = 3m$. This point lies between the two inner corners of the edge column on the x-axis. The results at the location will be compared across different mesh densities to evaluate the sensitivity of the moments and stresses to different modelling choices.

The centre-to-centre distance between the columns is 4.85 metres, resulting in a span-to-thickness ratio of 24.25, which is significantly greater than five. This means that, in theory, the Kirchhoff plate theory is expected to provide more reliable results when modelling the floor behaviour.

3.2 2D Plate Model

The 2D plate model will be made using SCIA Engineer 25.0 Student Version. This software allows moment and stress analyses based on Kirchhoff and on Mindlin–Reissner plate theories. A comparison of the results obtained from both theoretical models will therefore be made.

SCIA's default mesh settings are used, in which elements consist of a combination of quadrangles and triangles. Mesh refinement is applied, the initial mesh has an average 2D

element size of 400 mm, and this size is halved until a final element size of 25 mm. Further details on the meshing and calculation settings can be found in Appendix C.

The results for the moments m_x and m_y will be examined. m_{xy} is expected to be about zero due to symmetry. Another set of results examined are the stresses. SCIA Engineer provides several types of stresses. The method used to calculate them is explained on their website and is shown below (SCIA Engineer, n.d.). The stresses of interest are the normal stresses in the x-direction and y-direction at both the top and bottom of the plate. How they are calculated can be seen below.

$$\sigma_x^+ = \frac{n_x}{h} + \frac{6m_x}{h^2} \qquad \sigma_x^- = \frac{n_x}{h} - \frac{6m_x}{h^2} \tag{3.1}$$

$$\sigma_y^+ = \frac{n_y}{h} + \frac{6m_y}{h^2} \qquad \sigma_y^- = \frac{n_y}{h} - \frac{6m_y}{h^2} \tag{3.2}$$

The other aspects that will be measured are the local displacement, global maximum displacement, and the reaction force in the centre column.

3.2.1 Column Model

The column model represents a support configuration where a 1D column is positioned at the centre of each 3D location of the column. Although it is a 1D column in SCIA it has dimensions of 300 mm by 300 mm.

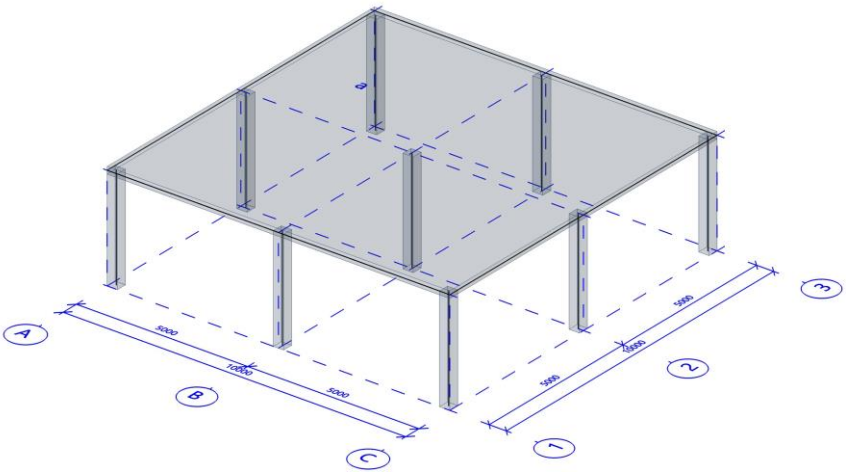

Figure 3.3: Column Model Structure

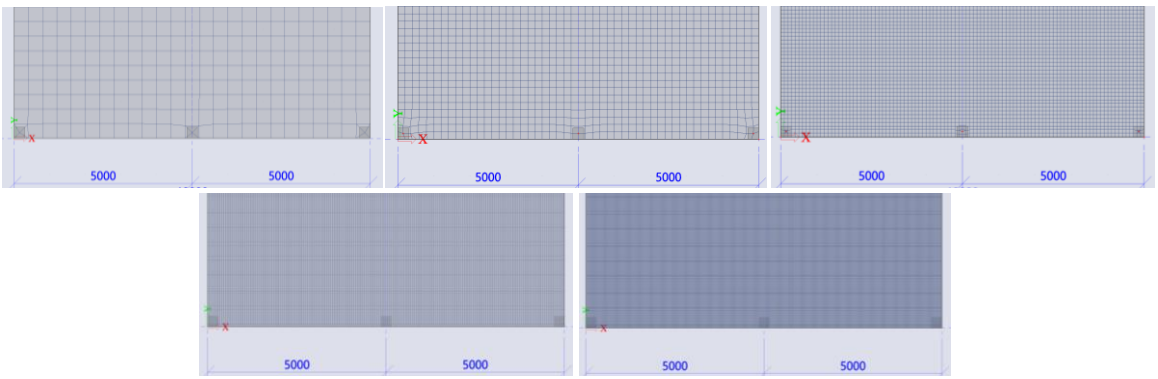

Figure 3.2: Mesh from top left to right (400mm, 200mm, 100mm), from bottom left to right (50mm, 25mm)

3.2.2 Spring Model

The spring model is a support configuration in which the floor is supported by four smaller columns that simulate the behaviour of springs. Because these columns are fixed to the plate, they act not only as axial springs, resisting forces along their axis, but also as bending springs, as they resist forces that cause the plate to bend. The centre of these columns is positioned such that their centre coincides with the corners of the 3D edge column. The spring model was constructed only at the position of the edge column where the data was collected. The remaining columns were kept unchanged, meaning they resembled those in the original column model. Each column has a cross-section of 150 mm by 150 mm. The areas summed together result in the same area as the area of the edge column in the column model. The same mesh refinement is applied as in the column model.

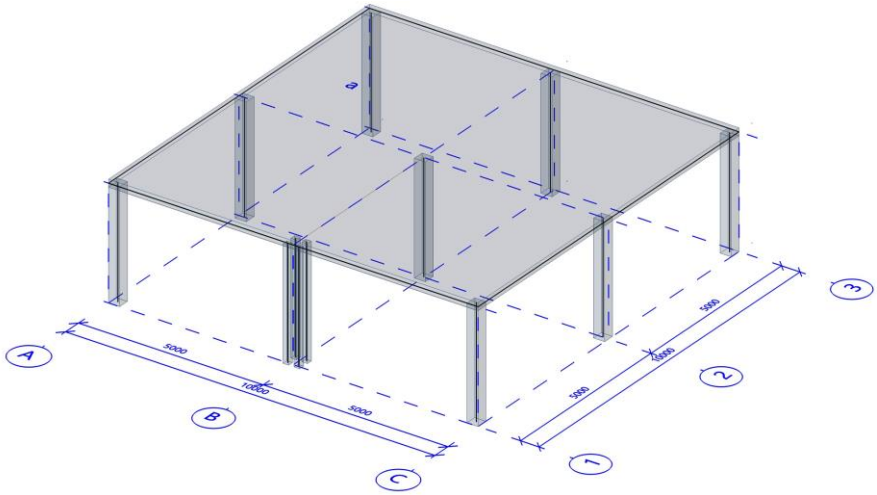

Figure 3.4: Spring Model Structure



Figure 3.5: Mesh from top left to right (400mm, 200mm, 100mm), from bottom left to right (50mm, 25mm)

3.3 3D Volume Model

The 3D model is created using ANSYS. When launching ANSYS Workbench, the first step is to define the material. Concrete is selected from the Engineering Data Sources and then adjusted to be more similar to the properties of the concrete used in SCIA. These adjustments are important to have an accurate comparison between the two software. Unfortunately, ANSYS offers limited options for modifying material properties.

The next step in Workbench involved launching the subprogram ANSYS Discovery to construct the geometry of the model. As the columns were connected with a fixed connection to the plate, the choice made was to model the whole structure (columns and plate) as one

single object. Once the model was completed, the next step was in ANSYS Mechanical, where the mesh was generated, loads and supports were applied, and the required calculations were set up.

The mesh was created using the hex-dominant method, using mainly quadrilateral elements. This produced a mesh that resembled more the mesh used in the 2D model, although triangular elements were still created. To avoid excessive refinement in areas where no data was collected, two different face sizing settings were applied. The first face sizing was assigned to the top and bottom surfaces of the plate. Only these mesh sizes were adjusted during the experiment. The second face sizing was applied to the rest of the structure, set at a fixed value of 100 mm, and kept constant across all test cases. All meshes can be seen in Appendix D.

The applied loads included a standard earth gravity load to simulate the self-weight of the structure, as well as a pressure load of 0.01 MPa (equivalent to 10 kN/m^2). Fixed supports were applied to the base of each column.

ANSYS can only directly calculate the displacement, stress and strain. The solutions were found using the probe stress tool. To determine σ_x^+, the normal stress in the x-direction at top of the plate $(x = 5m,\ y = 0.3m,\ z = 0.2m)$ was evaluated and similarly σ_x^- was determined by evaluating the normal stress at the bottom of the plate $(x = 5m,\ y = 0.3m,\ z = 0m)$. The same approach was used for stresses in the y-direction. Additional results considered included displacement at the top of the plate (same coordinates), the total reaction force of the centre column, and the global maximum deformation.

To calculate the bending moment, it is necessary to know the variation of stress over the height of the plate. The bending moment can then be determined numerically by discretising the following formula into *n* subregions (Bot, 2024).

$$m_x = \int_{\frac{t}{2}}^{\frac{t}{2}} \sigma_x \cdot y \cdot dy \approx \sum_{i=1}^{n} \sigma_{x,i} \cdot y_i \cdot \Delta y_i \tag{3.3}$$

To achieve this in ANSYS, a path was created from the bottom to the top of the plate at $x = 5m,\ y = 0.3m$. Using the linearised stress solver along this path, a table of stress values was generated. These tables can be seen in Appendix D. Using formula 3.3 the moments were found and plotted into the results. As SCIA uses the z-direction to be upwards, a minus had to be added to the moments in ANSYS to compensate for this.

4 Validation

This chapter explains the validation process for the models used in the project. It also tests an assumption made in the spring model and outlines the acceptability limits.

4.1 Model Validation

In this project, ensuring that the models are constructed correctly is important, as different programmes are used that model and calculate in different ways. To verify the accuracy of the models, two measurements unrelated to stresses and moments are checked in each one.

The reaction force at the centre column is the first variable used to validate the accuracy of the models. This variable is particularly useful for validation because, although it is highly dependent on the model, it should remain relatively stable if the model is constructed and the loads are applied correctly. Factors such as the choice of plate theory or mesh size should not significantly affect this value, allowing it to serve as a reliable indicator of model accuracy.
Since we are testing the model, a smaller deviation is considered acceptable. For this variable, the biggest difference is a deviation of 2.47 percent from the average (see Table 4.1). This is considered acceptable.

	Kirchhoff (column)					Mindlin (column)					ANSYS				
	400mm	200mm	100mm	50mm	25mm	400mm	200mm	100mm	50mm	25mm	400mm	200mm	100mm	50mm	25mm
Centre Column Reaction Force [kN]	483.41	487.16	488.57	490.68	492.11	484.49	488.94	492.36	496.13	499.12	479.98	479.6	479.54	479.7	479.73
Difference from average	-0.70%	0.07%	0.36%	0.79%	1.08%	-0.48%	0.44%	1.13%	1.88%	2.47%	-1.42%	-1.50%	-1.51%	-1.48%	-1.47%

	Kirchhoff (Springs)					Mindlin (springs)				
	400mm	200mm	100mm	50mm	25mm	400mm	200mm	100mm	50mm	25mm
Centre Column Reaction Force [kN]	482.27	484.5	485.61	487.2	488.3	482.24	485.66	488.18	491.1	493.4
Difference from average	-0.94%	-0.48%	-0.25%	0.09%	0.32%	-0.95%	-0.24%	0.28%	0.87%	1.34%

Table 4.1: Centre Column Reaction force and differences from average

The second variable used to validate the accuracy of the model is the global maximum displacement. For this variable, the deviations are larger compared to the reaction force at the centre of the structure. Across all models, the difference from the average tends to increase as the element size decreases, this is like due to singularities occurring. The maximum observed deviation is 7.42 percent from the average (see Table 4.2). Since this variable can vary due to several factors, this level of deviation is deemed acceptable.

	Kirchhoff (column)					Mindlin (column)					ANSYS				
	400mm	200mm	100mm	50mm	25mm	400mm	200mm	100mm	50mm	25mm	400mm	200mm	100mm	50mm	25mm
Maximum displacement [mm]	3.9	3.8	3.9	3.9	3.68	3.9	4	3.9	4	3.69	3.9	4.2	4	4.2	3.68
Difference from average	-0.81%	-3.46%	-0.81%	-0.81%	-6.84%	-0.81%	1.71%	-0.81%	1.71%	-6.55%	-0.81%	6.39%	1.71%	6.39%	-6.84%

	Kirchhoff (Springs)					Mindlin (springs)				
	400mm	200mm	100mm	50mm	25mm	400mm	200mm	100mm	50mm	25mm
Maximum displacement [mm]	3.9	4.1	3.9	4.1	3.66	3.9	4.2	4	4.2	3.68
Difference from average	-0.81%	4.11%	-0.81%	4.11%	-7.42%	-0.81%	6.39%	1.71%	6.39%	-6.84%

Table 4.2: Maximum displacement and differences from average

4.2 Spring Model Assumption Testing

It was assumed that only modifying the edge column where the data was obtained from would be sufficient, and that changing the others would not have a significant impact on the results. To test this assumption, an alternative model was created in which all columns of the structure were replaced by springs. This model was evaluated using the same parameters as the original spring model at the same point ($x = 5m,\ y = 0.3m,\ z = 3m$). In both cases, the analysis was conducted using a mesh with an element size of 200 mm, based on the Kirchhoff plate theory.

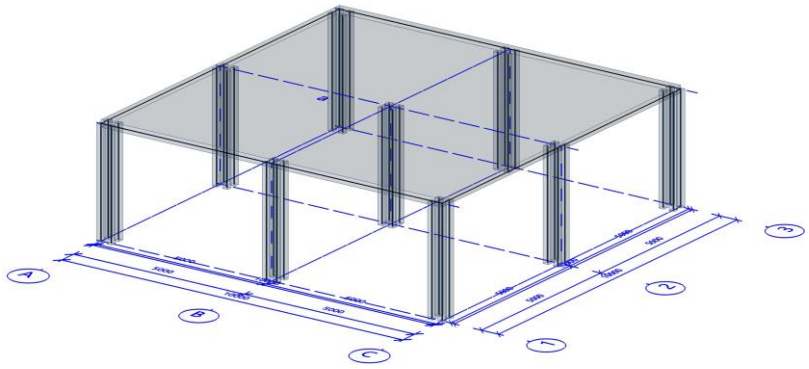

Figure 4.1: Model with only springs

Kirchhoff 200mm	m_x [kNm/m]	m_y [kNm/m]	σ_x^+ [MPa]	σ_x^- [MPa]	σ_y^+ [MPa]	σ_y^- [MPa]
Spring model	-49.21	-34.88	7.4	-7.4	5.2	-5.3
all springs	-47.80	-33.41	7.2	-7.2	5	-5
Difference	*-3%*	*-4%*	*-3%*	*-3%*	*-4%*	*-6%*

Table 4.3: Difference spring model and only springs model

The results from each test were reviewed to determine whether they fell within an acceptable range. If they did, the assumption was considered correct. Looking at the differences in Table 4.3, they are never greater than 5 percent, except for the stress in the direction of the y- axis. However, there is confidence that with more decimals, this difference would also fall around 5 percent. Therefore, the assumption is considered appropriate.

4.3 Acceptability Criteria

The 2D and 3D model results are compared. If the 2D model's moments, stress, and deflections are within 10 percent of the 3D model's, it is considered accurate. Larger differences suggest a limitation of the 2D model or a modelling error.

5 Results

This chapter presents the results obtained during the analysis. It begins by showing the global and local stresses and moments derived from both 2D and 3D plate models. Subsequently, it compares the 2D models to the 3D reference model, focusing on identifying the most accurate plate model and the optimal mesh size.

5.1 Global Deformations, Stresses and Moments

Global stresses and moments are shown using contour plots from SCIA and ANSYS. Since ANSYS does not produce any moments, there is no contour plot of moments from ANSYS.

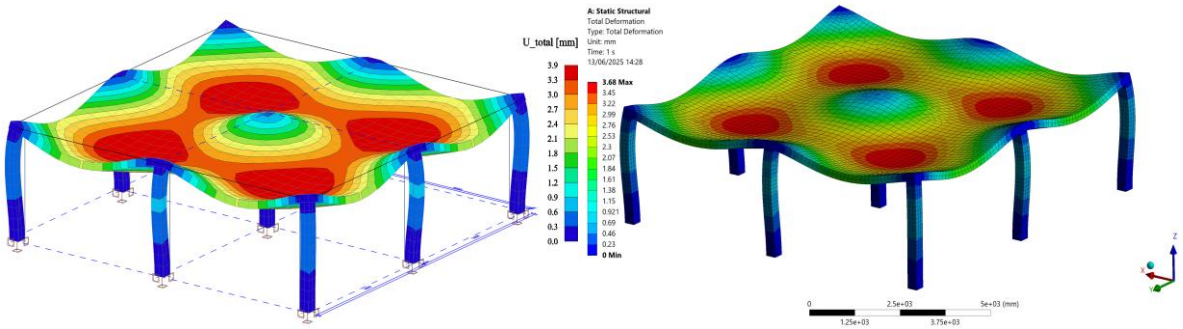

Figure 5.1: Deformations 2D SCIA (left) and 3D ANSYS (right)

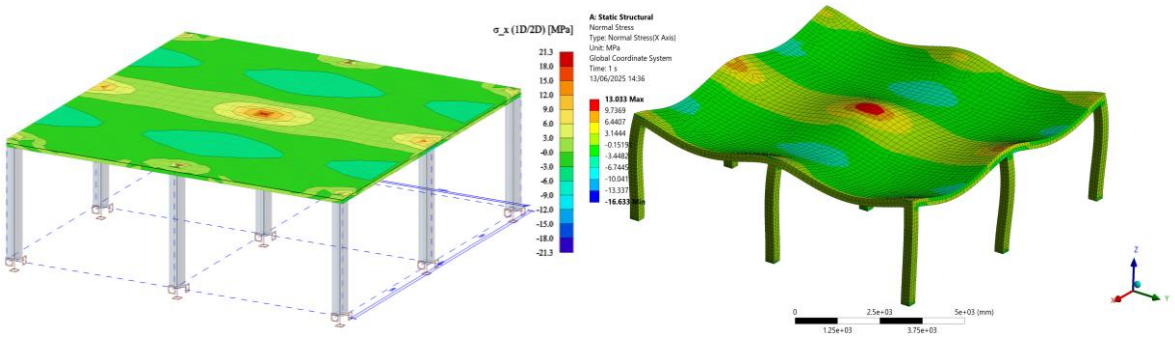

Figure 5.2: Stresses in x-direction 2D SCIA (left) and 3D ANSYS (right)

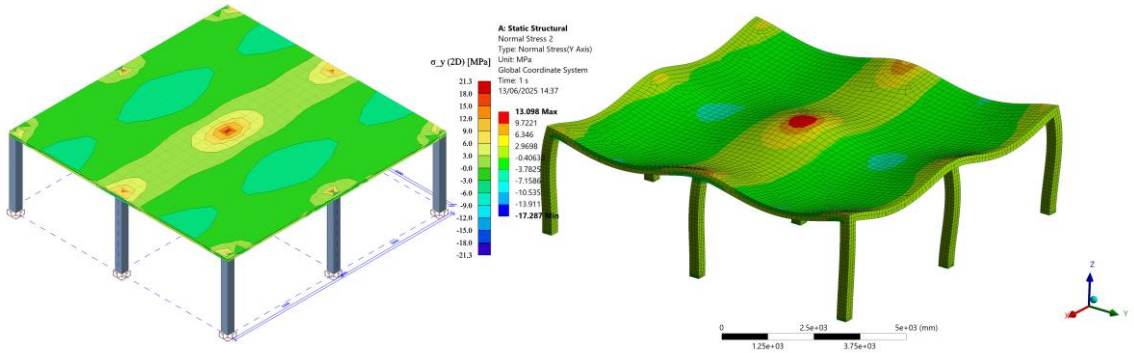

Figure 5.3: Stresses in y-direction 2D SCIA (left) and 3D ANSYS (right)

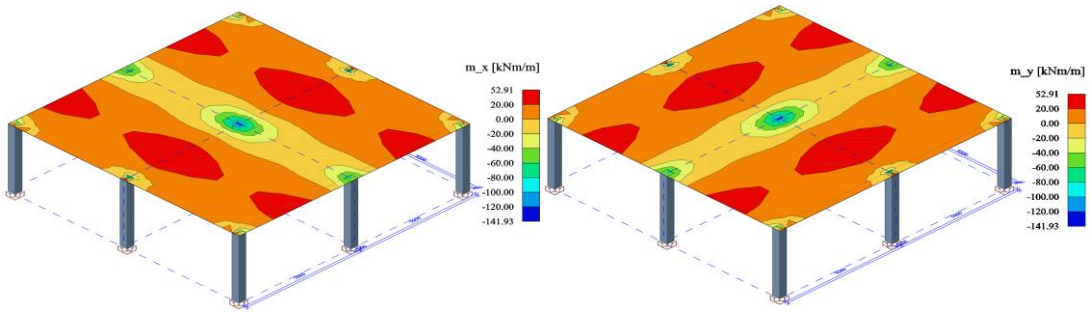

Figure 5.4: Contour plot m_x and m_y in SCIA

5.2 Local Stresses and Moments

The stresses and bending moments at the point $x = 5m \; and \; y = 0.3m$ were compared across the different models to assess the effect on the structural behaviour at that specific location.

5.2.1 Stresses

In figure 5.5 the ANSYS model shows nearly constant stress values at the top of the plate, reaffirming its reliability as a reference. In the 2D model, the support is represented by a one-dimensional column, a point, so it is expected that the column models would show stress singularities as the mesh is refined. However, this expected behaviour is not observed. This might be due to the mesh resolution or limitations within SCIA.

The graph for σ_y^- reveals a discrepancy at an average element size of 200 mm. This may be due to the fact that m_{xy} at this point is theoretically expected to be zero due to symmetry. However, it now has a non-zero value, which is especially high in the Mindlin column model. Although the exact cause for this non-zero value is unclear, it is likely related to the mesh configuration or limitations in SCIA.

At the bottom of the plate there is a corner point where the plate and column connect. As discussed in Section 2.2.2, a singularity is expected to emerge as the mesh size decreases. This singularity is clearly visible in the ANSYS model. None of the 2D models show signs of a singularity forming.

The Kirchhoff and Mindlin spring models align more closely with ANSYS. Although some data points exceed the previously defined ten percent limit, the average percentual differences for σ_x^+ are 10.35% and 9.44%, respectively. This makes these models to be considered somewhat accurate. In contrast, the column models do not achieve comparable accuracy. For σ_x^- before the singularity starts to show, the ANSYS model produces results that are also approximately within 10 percent of those from the spring models (see Appendix B).

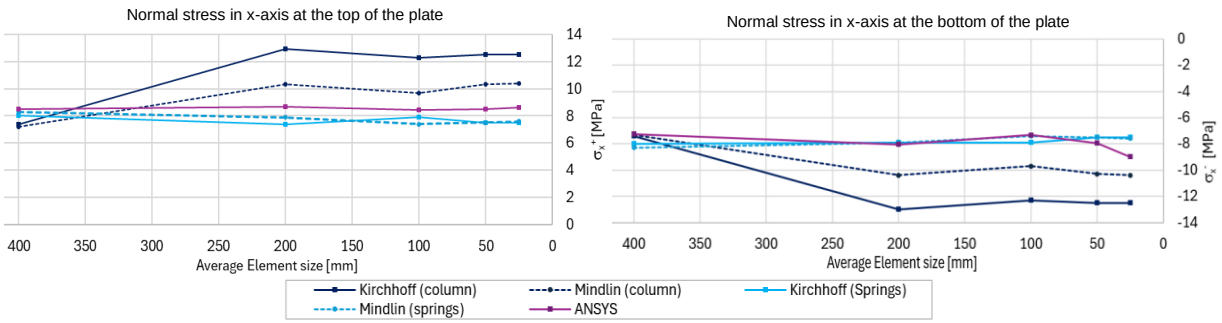

Figure 5.5: Normal Stress in x-direction.

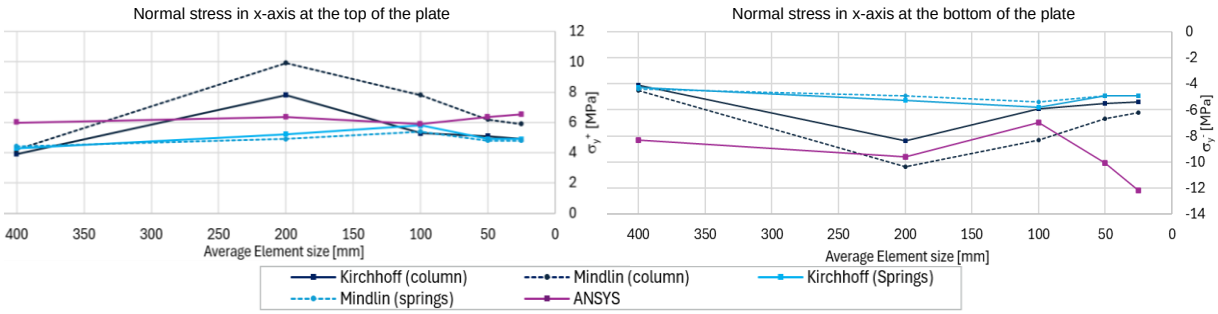

Figure 5.6: Normal stress in y-direction

5.2.2 Moments

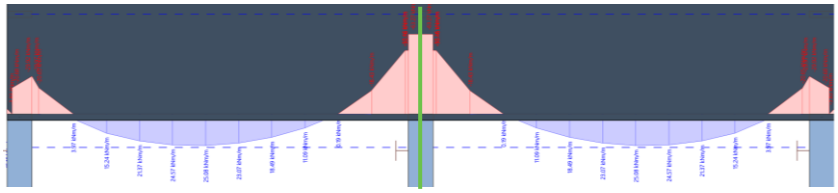

Figure 5.7: Moment line m_{xx} SCIA 400mm Kirchhoff (green line is location of datapoint)

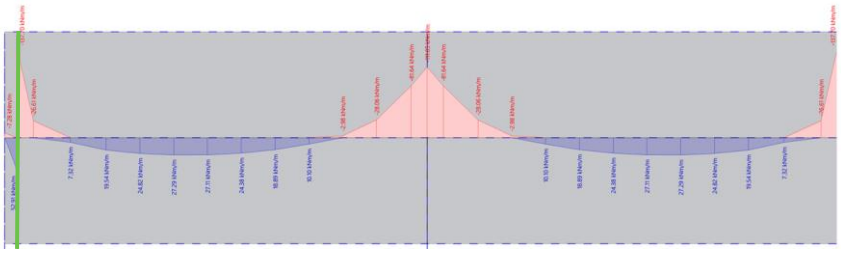

Figure 5.8: Moment line m_{yy} SCIA 400mm Kirchhoff (green line is location of datapoint)

The ANSYS model shows nearly constant bending moments values, again showing its reliability. The bending moments of the spring models in the x-direction are quite accurate. As shown in Table B.1, the average percentual difference in m_x compared to ANSYS is 6.53% for the Kirchhoff spring model and 5.77% for the Mindlin spring model, with all values within the acceptable limit.
In contrast, the moments in the y-direction are less accurate. This reduced accuracy is likely due to the proximity of the evaluated point to the plate edge in the y-direction.

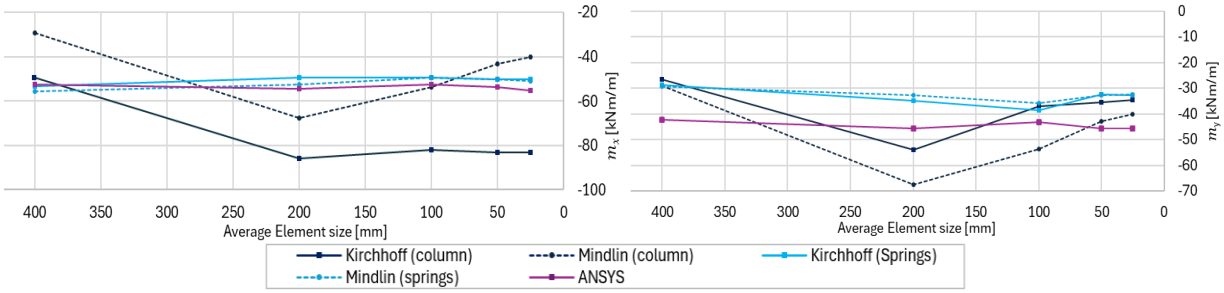

Figure 5.9: Bending moments in the x-direction and y-direction

5.3 Comparison of moment and stress distributions between 2D and 3D

As shown in figures 5.5 and 5.9, the 3D ANSYS model serves as a reliable reference. With this established, the objective is to identify which 2D model and mesh size produces results most similar to the accurate ANSYS model.
To analyse this, graphs and tables have been created to show the percentual differences between each model and the ANSYS results. These comparisons are provided in Appendix B. From these tables and graphs, two summary graphs were made by averaging the percentual differences. Those graphs offer a clear overview of the models and mesh size performance for each measurement.

5.3.1 Accuracy Comparison of Plate Models

To determine which model has the highest level of accuracy, the average absolute percentual difference from the ANSYS reference model was analysed for all mesh sizes. The results are presented in Figure 5.10. As previously mentioned, the accuracy of measurements in the x-direction differs from those in the y-direction, primarily due to the proximity of the evaluated point to the plate edge in the y-direction. Therefore, each direction is assessed separately.

X-direction measurements:

Several clear trends emerge for measurements in the x-direction. The first visible trend is that the Mindlin-Reissner plate theory is consistently more accurate than the Kirchhoff theory, both in the column and spring models.
Secondly, the use of springs significantly improves accuracy in both plate theories. For measurements in the x-direction, Kirchhoff and Mindlin spring models achieve percentual errors within or close to the acceptable threshold of ten percent. In contrast, the column models show much higher errors, often two to four times the acceptable limit. Based on this analysis, the most accurate model for measurements in the x-direction is the Mindlin-Reissner plate theory using a spring model.

Y-direction measurements:

Finding clear trends in the y-direction is more difficult. In general, accuracy is lower compared to the x-direction. This may be explained by the proximity of the evaluated point to the plate edge in the y-direction. As seen in the global results, this region shows substantial stress variation over a small surface area. This amplifies any limitations of the 2D software.

In particular, the variable σ_y^- is very inaccurate. This is due to the inability of the 2D software to represent the stress singularity occurring at a corner point in the same way a 3D software would. The same level of inaccuracy does not appear for σ_x^-, because the singularity in that direction is less developed (see Figure 5.5 and Figure 5.10). It is expected that further mesh refinement will also lead to greater inaccuracies in σ_x^-. With the current results, no conclusions can be made about which plate theory or model is the most accurate in the y-direction.

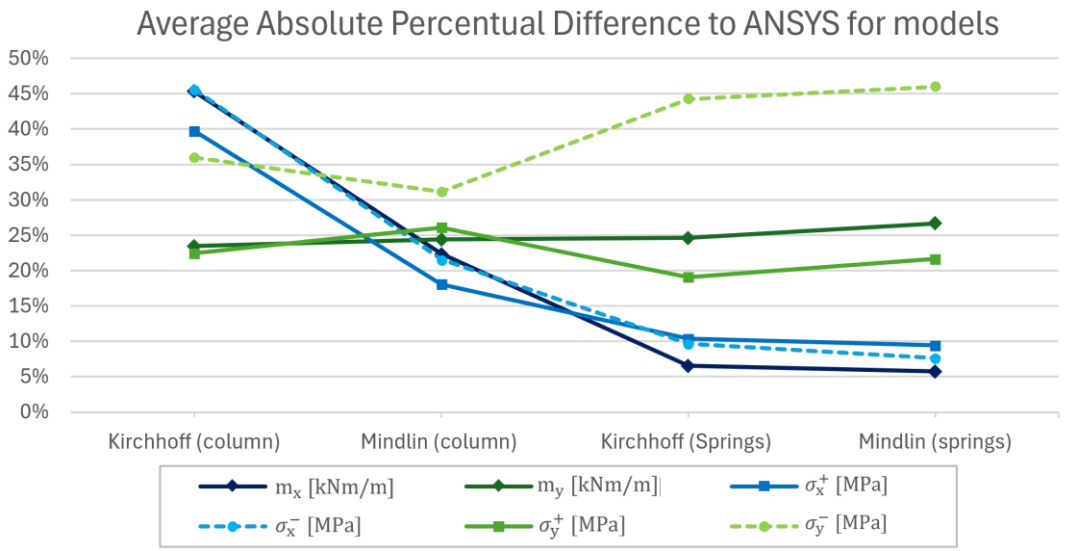

Figure 5.10: Average Absolute Percentual Difference to ANSYS Across Mesh Types and Plate Models

5.3.2 Effect of Mesh Refinement

To evaluate the impact of mesh refinement on the accuracy of the 2D models relative to the ANSYS, the average absolute percentual differences for different measurements were analysed for five mesh sizes. The results are shown in Figure 5.11.

The stress singularity of σ_y^- that is created can be clearly observed. This variable deviates significantly from the others and will therefore be ignored from further conclusions.

At a mesh size of 400 mm, the measurements in the x-direction show the highest accuracy, with percentual difference within the acceptable limit of 10 percent. In contrast, the measurements in the y-direction achieve their lowest error at a mesh size of 100 mm, although these values still far exceed the acceptability limit.

As the mesh is refined, there is no improvement in accuracy. However, refinement does lead to improved consistency across measurements. Initially, there is considerable variation in percentual difference between measurements. At finer mesh sizes all measurements (excluding σ_y^-) converge towards similar error values. Specifically, at 25 mm, these remaining measurements lie within a range of one percent around a 22.5 percent difference from ANSYS.

This trend indicates that while mesh refinement does not necessarily increase the absolute accuracy of the 2D models, it does lead to more stable and predictable results across different structural measurements.

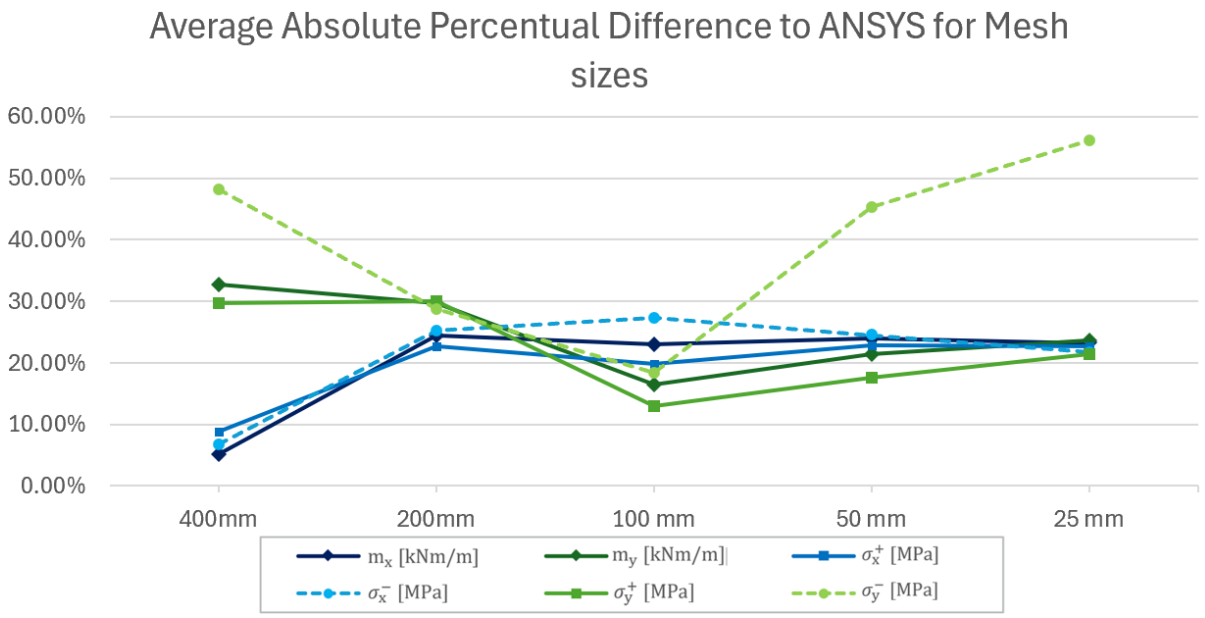

Figure 5.11: Average Absolute Percentual Difference to ANSYS Across Models

6 Discussion and Recommendation for Future Work

This research has led to several interesting observations into the accuracy of different structural analysis software and different modelling approaches. During the research, I have developed a great interest in these topics. This has led to some observations for improvement in the methodology used in this report and opportunities for potential future research.

6.1 Discussion

Several observations were made about things that could be improved in the methodology used in this report. One key observation concerns the decision to use the global maximum displacement as a validation measure. Although the deviation observed was small enough to rule out major modelling errors, this variable is influenced by too many factors. The location of the point with maximum displacement varied depending on the model or mesh size, making it an unreliable reference. To allow for more consistent comparisons, a more effective approach would have been to select a fixed location known to show major displacement, such as $(x = 5m, y = 5m)$.

Another area where improvements could have been made was to choose multiple data points. The chosen point showed interesting behaviour in the 3D model, such as the development of a stress singularity and showed anomalies in the y-direction that were important for the conclusion. However, analysing additional points further from the plate edges, would have reassured the conclusion. The hypothesis is that measurements taken further away from boundary regions, where singularities are less pronounced, would produce 2D model results more similar with those from 3D simulations.

6.2 Future work

Future research could focus on expanding the dataset and broadening the scope of analysis. This study examined a single scenario using one 2D and one 3D software package. A more comprehensive comparison across multiple 2D and 3D software would provide deeper insights into their relative accuracies and limitations.

Additionally, future research could explore a wider range of structural configurations. While related work, such as that by Yannick Bot on circular plates, has contributed useful findings, further studies could investigate different geometries, boundary conditions, and loading scenarios to assess the validity of the application of 2D modelling techniques across various structures.

7 Conclusion

This report uses sub-questions to guide the answer to the main research question. Therefore, conclusions will first be drawn for each sub-question, followed by a conclusion addressing the main question.

Sub-question 1: *"Do both the Kirchhoff and the Mindlin-Reissner plate theory yield results that align closely enough with the 3D model".*

As the plate modelled in this report is thin, the theory suggests that shear deformation should be negligible, making the Kirchhoff plate theory theoretically the more appropriate choice. However, as shown in Figure 5.10, the Mindlin-Reissner theory, when applied to both the column and spring models, consistently shows greater accuracy for measurements in the x-direction. In the y-direction it is difficult to identify consistent trends. Accuracy is generally lower, likely due to the evaluated point's proximity to the plate edge, where steep stress gradients exaggerate the limitations of the 2D models. Given the current results, no definitive conclusion can be drawn regarding which plate theory performs better in this direction.

This raises the question of whether shear deformation is negligible. The high accuracy of the 3D reference models lies partially in the ability to account for everything, even shear deformation no matter how small. However, as the accuracy of the 2D model improves, particularly in the x-direction, the additional benefit of including shear deformation diminishes. This implies that for sufficiently accurate models, the effect of including shear deformation becomes negligible. In contrast, in less accurate models, accounting for shear deformation can make a meaningful difference and should therefore not be ignored.

Sub-question 2: *"Is the use of four springs to model a column valid?"*

The use of four springs to model a column is valid in structural engineering practice and according to the findings actually strongly recommended. The four-spring model significantly improves the accuracy of 2D plate theories when compared to column models, particularly for measurements in the x-direction. Both Kirchhoff and Mindlin-Reissner theories benefit from the use of springs, with errors reduced from about 40 percent to within or near the acceptable 10 percent threshold. However, for the y-direction, no clear conclusions can be made due to lower accuracy and the presence of stress singularities.

Sub-question 3: *"Is the use of a point support to model an edge column valid?"*

The use of a point support to model an edge column is not considered valid. Where the parameter values are recorded, the edge of the column contributes greatly to the structural behaviour, as it provides direct support to the plate. In the 2D model, this contribution is less apparent, as the one-dimensional column does not provide direct support. As a result, representing the column as a point support may fail to accurately show bending moments and stresses close to the edge column.

Sub-question 4: *"What is the optimal size for finite elements to ensure accuracy in the model?"*

A mesh size equal to twice the plate thickness provides the highest accuracy for measurements in the x-direction, with errors remaining within the acceptable 10 percent threshold. Further mesh refinement does not improve absolute accuracy but does enhance consistency across measurements, as errors begin to converge at finer mesh sizes. Therefore,

if the designer prioritises higher accuracy in specific directions, a mesh size of twice the plate thickness is appropriate. However, if consistent error levels across all measurements are more important, a finer mesh should be used.

Main research question: ***"Does the 2D model give the same moments and stresses as the 3D model? Is the deviation acceptable?"***

The 2D models do not produce the same moments and stresses as the 3D volume model, but under certain conditions, they can provide results that are sufficiently accurate for engineering purposes. This report only models a specific structure and gets results from one specific location, it is therefore hard to give a global answer to this research question.
For the results obtained in this study it shows that in the x-direction, the Mindlin-Reissner plate theory, particularly when combined with a four-spring column model and a mesh size equal to twice the plate thickness, yields acceptable differences. In contrast, the y-direction shows inaccurate results and more variability, largely due to stress singularities and edge effects that 2D models cannot represent accurately.

Overall, while 2D models, especially those using spring supports and appropriate mesh sizes, can approximate 3D results well in certain directions, care must be taken in interpreting results near edges or in regions prone to singularities.

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Appendix A: Results table

Description	Average 2D Element size	number of nodes	2D Elements	1D Elements	m_x [kNm/m]	m_y [kNm/m]	m_xy [kNm/m]	v_x [kN/m]	v_y [kN/m]	σ_x+ [MPa]	σ_x- [MPa]	σ_y+ [MPa]	σ_y- [MPa]	τ_xy+ [MPa]	τ_xy- [MPa]	τ_xz+ [MPa]	τ_xz- [MPa]	τ_yz+ [MPa]	Deflection [mm]	Max Deflection [mm]	Centre Column Reaction Force [kN]
Kirchhoff (column)	400	694	952	9	-49.47	-26.61	0.00	0.00	149.51	7.40	-7.40	3.90	-4.10	0.00	0.00	0.00	0.00	-1.10	0.50	3.90	483.41
Mindlin (column)	400	694	952	9	-48.48	-29.03	0.00	0.00	168.93	7.20	-7.30	4.20	-4.50	0.00	0.00	0.00	0.00	-1.30	0.50	3.80	484.49
Kirchhoff (Springs)	400	697	652	12	-53.37	-28.77	0.00	0.00	-37.69	8.00	-8.00	4.30	-4.30	0.00	0.00	0.00	0.00	0.30	0.50	3.90	482.27
Mindlin (springs)	400	697	652	12	-55.60	-29.49	0.00	0.00	143.78	8.30	-8.30	4.40	-4.40	0.00	0.00	0.00	0.00	0.50	0.50	3.90	482.24
ANSYS	400	44,040	11,716	0	-52.58	-42.37	0.00	0.00		8.48	-7.26	5.97	-8.34	-0.18	-0.03	0.00	-4.65	-0.12	0.44	3.68	479.98
Kirchhoff (column) 200mm	200	2,610	2,500	9	-86.04	-54.12	1.90	-184.16	572.87	12.90	-13.00	7.80	-8.40	0.30	-0.20	1.40	1.40	-4.30	0.50	3.90	487.16
Mindlin (column) 200mm	200	2,610	2,500	9	-69.15	-67.62	12.93	-146.77	617.05	10.30	-10.40	9.90	-10.40	1.90	2.00	1.10	1.10	-4.60	0.50	4.00	488.94
Kirchhoff (Springs) 200mm	200	2,613	2,500	12	-49.21	-34.88	0.02	1.42	4.25	7.40	-7.40	5.20	-5.30	0.00	0.00	0.00	0.00	0.00	0.50	3.90	484.50
Mindlin (springs) 200mm	200	2,613	2,500	12	-52.68	-32.78	0.10	1.67	2.80	7.90	-7.90	4.90	-4.90	0.00	0.00	0.00	0.00	0.00	0.50	4.00	485.66
Kirchhoff (all springs) 200mm	200	2,637	2,500	36	-47.80	-33.41	0.02	1.44	4.56	7.20	-7.20	5.00	-5.00	0.00	0.00	0.00	0.00	0.00	0.40		
ANSYS 200mm	200	47,434	10,432	0	-54.43	-45.51	0.00	0.00		8.68	-8.04	6.34	-9.63	-0.06	-0.11	0.17	-3.62	0.02	0.44	3.69	479.60
Kirchhoff (column) 100mm	100	10,218	10,020	9	-81.93	-37.10	0.00	0.00	734.52	12.30	-12.30	5.30	-5.90	0.00	0.00	0.00	0.00	-5.50	0.50	3.90	488.57
Mindlin (column) 100mm	100	10,218	10,020	9	-64.77	-53.66	0.00	0.00	589.95	9.70	-9.70	7.80	-8.30	0.00	0.00	0.00	0.00	-4.40	0.50	4.10	492.36
Kirchhoff (Springs) 100mm	100	10,222	10,021	12	-49.29	-38.69	0.00	0.00	-24.53	7.90	-7.90	5.80	-5.80	0.00	0.00	0.00	0.00	0.20	0.50	3.90	485.61
Mindlin (springs) 100mm	100	10,222	10,021	12	-49.32	-35.88	0.00	0.00	-4.29	7.40	-7.40	5.40	-5.40	0.00	0.00	0.00	0.00	0.00	0.50	4.10	488.18
ANSYS 100mm	100	135,092	27,665	0	-52.37	-43.26	0.00	0.00	0.00	8.46	-7.32	5.88	-6.97	-0.01	-0.11	0.03	-3.62	-0.01	0.43	3.66	479.54
Kirchhoff (column) 50mm	50	40,410	40,000	9	-83.13	-35.57	0.00	0.00	459.18	12.50	-12.50	5.10	-5.50	0.00	0.00	0.00	0.00	-3.40	0.50	3.90	490.68
Mindlin (column) 50mm	50	40,410	40,000	9	-68.58	-43.00	0.00	0.00	416.54	10.30	-10.30	6.20	-6.70	0.00	0.00	0.00	0.00	-3.10	0.50	4.20	496.13
Kirchhoff (Springs) 50mm	50	40,413	40,000	12	-49.99	-32.55	0.00	0.00	-26.15	7.50	-7.50	4.90	-4.90	0.00	0.00	0.00	0.00	0.20	0.50	4.00	487.25
Mindlin (springs) 50mm	50	40,413	40,000	12	-50.25	-32.59	0.00	0.00	5.97	7.50	-7.50	4.80	-4.90	0.00	0.00	0.00	0.00	0.00	0.50	4.20	491.10
ANSYS 50mm	50	961,045	241,558	0	-53.58	-45.71	0.00	0.00		8.52	-7.95	6.37	-10.06	0.00	0.01	0.00	-5.55	0.00	0.44	3.68	479.70
Kirchhoff (column) 25mm	25	160,810	160,000	9	-83.16	-34.44	0.00	0.00	451.08	12.50	-12.50	4.90	-5.40	0.00	0.00	0.00	0.00	-3.40	0.50	3.90	492.11
Mindlin (column) 25mm	25	160,810	160,000	9	-69.03	-40.26	0.00	0.00	389.06	10.40	-10.40	5.90	-6.20	0.00	0.00	0.00	0.00	-2.90	0.60	4.20	499.12
Kirchhoff (Springs) 25mm	25	160,813	160,000	12	-50.17	-32.75	0.00	0.00	-20.33	7.50	-7.50	4.90	-4.90	0.00	0.00	0.00	0.00	0.20	0.50	4.00	488.37
Mindlin (springs) 25mm	25	160,813	160,000	12	-50.77	-32.47	0.00	0.00	5.85	7.60	-7.60	4.80	-4.90	0.00	0.00	0.00	0.00	0.00	0.50	4.20	493.40
ANSYS 25mm	25	5,755,347	1,465,054	0	-55.10	-45.80	0.00	0.00		8.60	-8.97	6.52	-12.20	0.00	-0.02	0.00	-7.94	0.00	0.44	3.68	479.73

Table A.1: All Results

Appendix B: Difference Tables and Graphs

m_x [kNm/m]	400mm	200mm	100 mm	50 mm	25 mm	
ANSYS	**-52.58**	**-54.43**	**-52.37**	**-53.58**	**-55.10**	**Average**
Kirchhoff (column)	5.91%	-58.06%	-56.44%	-55.15%	-50.93%	45.30%
Mindlin (column)	7.79%	-27.04%	-23.68%	-28.00%	-25.28%	22.36%
Kirchhoff (Springs)	-1.51%	9.60%	5.88%	6.70%	8.95%	6.53%
Mindlin (springs)	-5.75%	3.22%	5.82%	6.21%	7.86%	5.77%
Average	5.24%	24.48%	22.96%	24.02%	23.25%	

Table B.1: m_x percentage difference compared to ANSYS

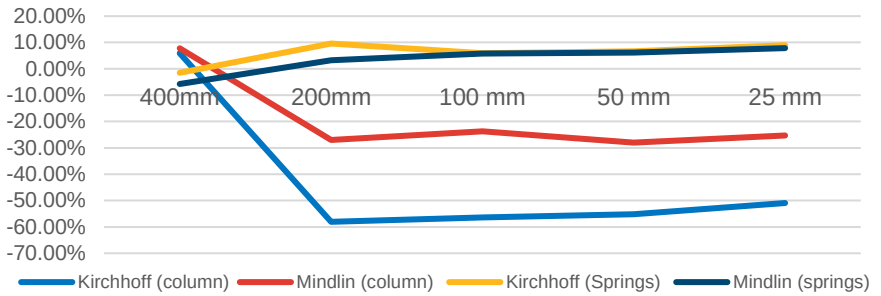

Figure B.1: m_x percentage difference compared to ANSYS

m_y [kNm/m]	400mm	200mm	100 mm	50 mm	25 mm	
ANSYS	**-42.37**	**-45.51**	**-43.26**	**-45.71**	**-45.80**	**Average**
Kirchhoff (column)	37.19%	-18.92%	14.24%	22.18%	24.80%	23.47%
Mindlin (column)	31.48%	-48.58%	-24.04%	5.93%	12.10%	24.43%
Kirchhoff (Springs)	32.09%	23.36%	10.56%	28.79%	28.49%	24.66%
Mindlin (springs)	30.39%	27.97%	17.06%	28.70%	29.10%	26.65%
Average	32.79%	29.71%	16.48%	21.40%	23.62%	

Table B.2: m_y percentage difference compared to ANSYS

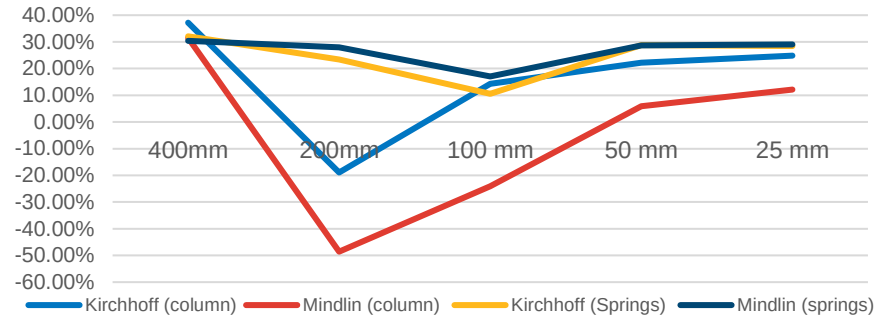

Figure B.2: m_y percentage difference compared to ANSYS

σ_x^+ [MPa]	400mm	200mm	100 mm	50 mm	25 mm	
ANSYS	**8.48**	**8.68**	**8.46**	**8.52**	**8.60**	**Average**
Kirchhoff (column)	12.69%	-48.67%	-45.42%	-46.65%	-45.30%	39.74%
Mindlin (column)	15.05%	-18.70%	-14.68%	-20.84%	-20.89%	18.03%
Kirchhoff (Springs)	5.61%	14.72%	6.60%	12.01%	12.82%	10.35%
Mindlin (springs)	2.07%	8.96%	12.51%	12.01%	11.66%	9.44%
Average	8.85%	22.76%	19.80%	22.88%	22.67%	

Table B.3: σ_x^+ percentage difference compared to ANSYS

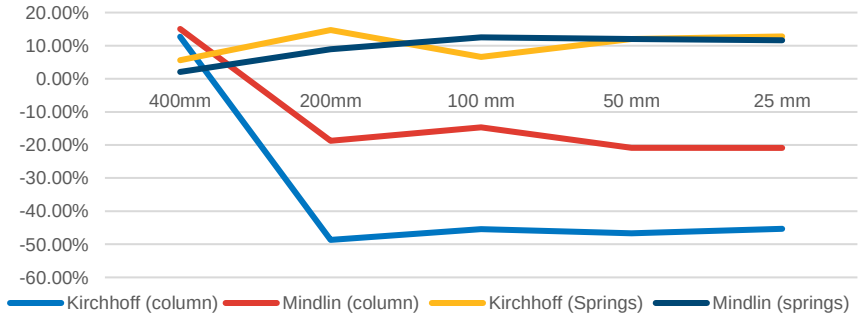

Figure B.3: σ_x^+ percentage difference compared to ANSYS

σ_x^- [MPa]	400mm	200mm	100 mm	50 mm	25 mm	
ANSYS	**-7.26**	**-8.04**	**-7.32**	**-7.95**	**-8.97**	**Average**
Kirchhoff (column)	-1.95%	-61.63%	-68.00%	-57.25%	-39.30%	45.62%
Mindlin (column)	-0.57%	-29.30%	-32.48%	-29.58%	-15.90%	21.57%
Kirchhoff (Springs)	-10.21%	8.00%	-7.90%	5.65%	16.42%	9.64%
Mindlin (springs)	-14.34%	1.78%	-1.07%	5.65%	15.31%	7.63%
Average	6.77%	25.18%	27.36%	24.53%	21.73%	

Table B.4: σ_x^- percentage difference compared to ANSYS

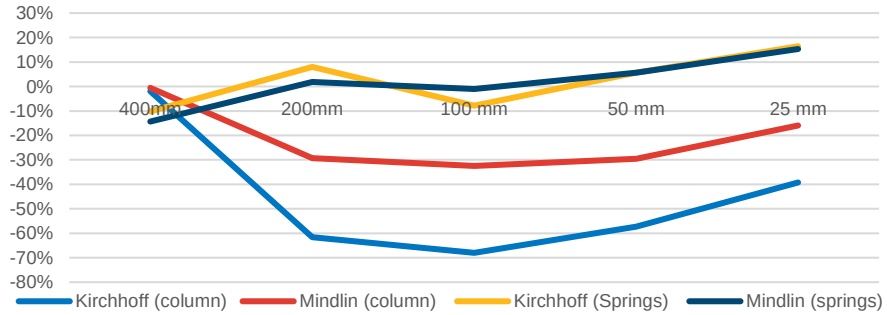

Figure B.4: σ_x^- percentage difference compared to ANSYS

σ_y^+ [MPa]	400mm	200mm	100 mm	50 mm	25 mm	
ANSYS	**5.97**	**6.34**	**5.88**	**6.37**	**6.52**	**Average**
Kirchhoff (column)	34.70%	-23.01%	9.91%	19.89%	24.83%	22.47%
Mindlin (column)	29.68%	-56.13%	-32.58%	2.62%	9.49%	26.10%
Kirchhoff (Springs)	28.01%	17.99%	1.41%	23.03%	24.83%	19.06%
Mindlin (springs)	26.33%	22.73%	8.21%	24.61%	26.37%	21.65%
Average	29.68%	29.96%	13.03%	17.54%	21.38%	

Table B.5: σ_y^+ percentage difference compared to ANSYS

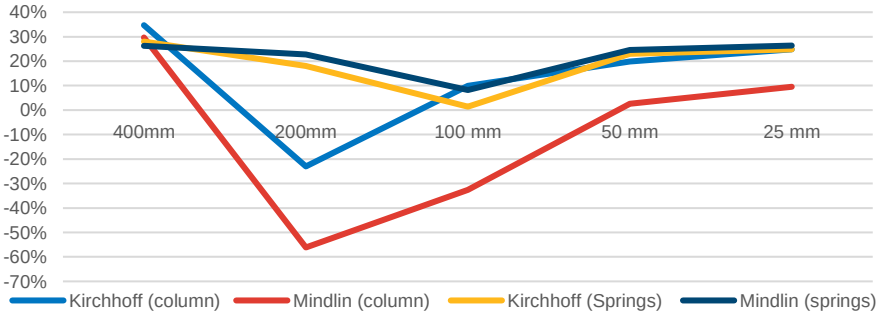

Figure B.5: σ_x^- percentage difference compared to ANSYS

σ_y^- [MPa]	400mm	200mm	100 mm	50 mm	25 mm	
ANSYS	**-8.34**	**-9.63**	**-6.97**	**-10.06**	**-12.20**	**Average**
Kirchhoff (column)	50.81%	12.74%	15.39%	45.34%	55.72%	36.00%
Mindlin (column)	46.01%	-8.04%	-19.03%	33.42%	49.16%	31.13%
Kirchhoff (Springs)	48.41%	44.94%	16.82%	51.31%	59.82%	44.26%
Mindlin (springs)	47.21%	49.10%	22.56%	51.31%	59.82%	46.00%
Average	48.11%	28.70%	18.45%	45.34%	56.13%	

Table B.6: σ_y^- percentage difference compared to ANSYS

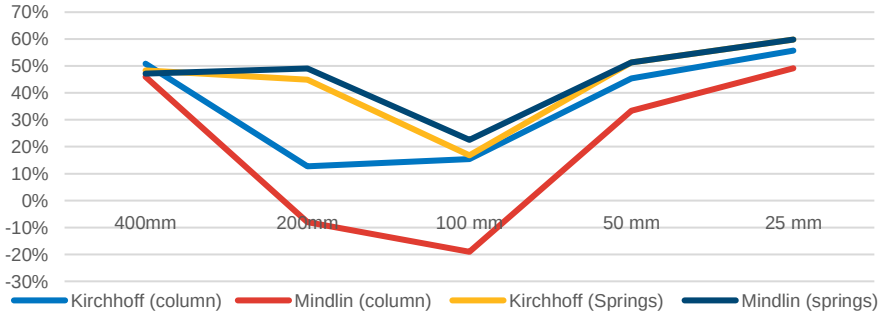

Figure B.6: σ_x^- percentage difference compared to ANSYS

Appendix C: SCIA Engineer Report

Student version

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2. Structure

2.1. Geometrie

2.1.1. Project

Functionality	Initial stress, Subsoil, Nonlinearity, Beam local nonlinearity, Support nonlinearity, Stability, Climatic loads, Structural model
No. of nodes :	22
No. of beams :	9
No. of slabs :	1
No. of used profiles :	1
No. of load cases :	2
No. of used materials :	2

2.1.2. Members

Name	Cross-section	Material	Length [m]	Beg. node	End node	Type
B2	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N3	N4	column (100)
B3	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N5	N6	column (100)
B4	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N7	N8	column (100)
B6	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N11	N12	column (100)
B7	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N13	N14	column (100)
B9	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N17	N18	column (100)
B10	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N1	N23	column (100)
B11	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N24	N25	column (100)
B12	CS1 - Rectangle (300.00; 300.00)	C30/37	3.000	N26	N27	column (100)

2.1.3. 2D members

Name	Layer	Type	Element type	Element behaviour	Material	Thickness type	Th. [mm]	FEM model
S1	Layer1	plate (90)	Standard	Standard FEM	C30/37	constant	200.00	Isotropic

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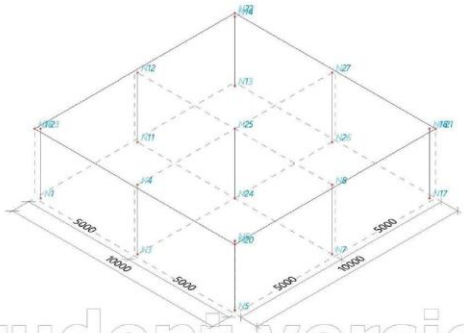
2.1.4. Knoopnummering



2.1.5. Randvoorwaarden

2.1.5.1. Nodal supports

Name	Node	System	Type	X Stiffness X [MN/m]	Y Stiffness Y [MN/m]	Z Stiffness Z [MN/m]	Rx Stiffness Rx [MNm/rad]	Ry Stiffness Ry [MNm/rad]	Rz Stiffness Rz [MNm/rad]
Sn1	N3	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Sn2	N24	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Sn3	N26	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Sn4	N5	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Sn5	N7	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Sn6	N17	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Sn7	N11	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Sn8	N13	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid
Sn9	N1	GCS	Standard	Rigid	Rigid	Rigid	Rigid	Rigid	Rigid

2.2. Materialen en doorsneden

2.2.1. Materials

Concrete EC2

Name	C30/37
Type	Concrete
ρ [kg/m³]	2500.00

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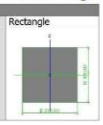
E_{mod} [MPa]	3.2800e+04
μ	0.2
α [m/mK]	0.01e-003
$f_{ck,28}$ [MPa]	30.00
Mean compressive strength fcm(28) [MPa]	38.00
Mean tensile strength fctm(28) [MPa]	2.90
fctk 0,05(28) [MPa]	2.00
fctk 0,95(28) [MPa]	3.80
Characteristic compressive cylinder strength fck(28) [MPa]	30.00

2.2.2. Doorsneden grafisch

CS1

Type	Rectangle
Afb	



2.2.3. Doorsneden tabel

Name	Colour	Type	Materiaal	A [mm²]	A_y [mm²]	I_x [mm⁴]	$W_{el,y}$ [mm³]	$W_{pl,y}$ [mm³]
		Detailed	Fabrication		A_z [mm²]	I_y [mm⁴]	$W_{el,z}$ [mm³]	$W_{pl,z}$ [mm³]
CS1		Rectangle 300.00; 300.00	C30/37 concrete	9.0000e+04	7.5000e+04 7.5000e+04	6.7500e+08 6.7500e+08	4.5000e+06 4.5000e+06	0.0000e+00 0.0000e+00

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3. Model 400mm

3.1. Berekening

3.1.1. Mesh setup

Name	Mesh0.05M
Generation of nodes in connections of beam elements	✗
Elastic mesh	✓
Use automatic mesh refinement	✗
Connect members/nodes	✓
Division on haunches and arbitrary members	5
Division for integration strip and 2D-1D upgrade	50
Average number of 1D mesh elements on straight 1D members	1
Average size of 2D mesh element [m]	0.400
Minimal length of beam element [m]	0.100
Maximal length of beam element [m]	1000.000
Average size of tendons, elements on subsoil, nonlinear soil spring [m]	1.000
Maximal out of plane angle of a quadrilateral [mrad]	30.0
Minimal distance between definition point and line [m]	0.001
Average size of panel element [m]	0.500
Definition of mesh element size for panels	Manual

3.1.2. Berekeningsverslag lineair

Linear calculation

Number of 2D elements	652
Number of 1D elements	9
Number of mesh nodes	694
Number of equations	4164
Bending theory	Kirchhoff
Load cases	Self weight, Additional load

Sum of loads and reactions

Load case	Value	X [kN]	Y [kN]	Z [kN]
Self weight	loads	0.00	0.00	-550.10
	reaction in nodes	0.00	0.00	550.10
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00
Additional load	loads	0.00	0.00	-1000.00
	reaction in nodes	0.00	0.00	1000.00
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00

3.2. Resultaten

3.2.1. Reacties

3.2.1.1. 1D internal forces

Linear calculation
Combination: SLS-Char (auto)
Coordinate system: Principal
Extreme 1D: Global
Selection: All

Name	dx [m]	Case	N [kN]	V_y [kN]	V_z [kN]	M_x [kNm]	M_y [kNm]	M_z [kNm]
B11	0.000	SLS-Char (auto)/1	**-484.53**	0.00	0.00	0.00	0.00	0.00
B3	3.000	SLS-Char (auto)/2	**-24.68**	3.76	3.76	**0.00**	7.58	7.58
B6	3.000	SLS-Char (auto)/1	-178.16	0.00	**-19.79**	0.00	**-39.90**	0.00
B4	3.000	SLS-Char (auto)/1	-178.16	0.00	**19.79**	0.00	**39.90**	0.00
B12	3.000	SLS-Char (auto)/1	-178.16	**-19.79**	0.00	0.00	0.00	**-39.90**
B2	3.000	SLS-Char (auto)/1	-178.16	**19.79**	0.00	0.00	0.00	**39.90**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load
SLS-Char (auto)/2	Self weight

3.2.2. Resultaten 2D-elementen

3.2.2.1. 2D internal forces

Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic magnitudes

Mesh	x [m]	y [m]	z [m]	Case	m_x [kNm/m]	m_y [kNm/m]	m_{xy} [kNm/m]	v_x [kN/m]	v_y [kN/m]
Element: 120; Node: 12	5.000	5.000	3.000	SLS-Char (auto)/1	**-141.93**	-111.05	0.00	0.00	-324.10
Element: 75; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**52.91**	-42.69	0.00	-328.38	0.00
Element: 121; Node: 12	5.000	5.000	3.000	SLS-Char (auto)/1	-111.05	**-141.93**	0.00	324.10	0.00
Element: 58; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	-42.69	**52.91**	0.00	0.00	328.38
Element: 61; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	-54.19	-56.39	**-33.04**	112.53	123.89
Element: 59; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	-54.19	-56.39	**33.04**	-112.53	123.89
Element: 118; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	-137.70	-115.46	0.00	**-1076.04**	0.00
Element: 119; Node: 8	0.150	5.000	3.000	SLS-Char (auto)/1	-137.70	-115.46	0.00	**1076.04**	0.00
Element: 124; Node: 13	5.000	9.850	3.000	SLS-Char (auto)/1	-115.46	-137.70	0.00	0.00	**-1076.04**
Element: 117; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	-115.46	-137.70	0.00	0.00	**1076.04**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

3.2.2.2. 2D stress/strain

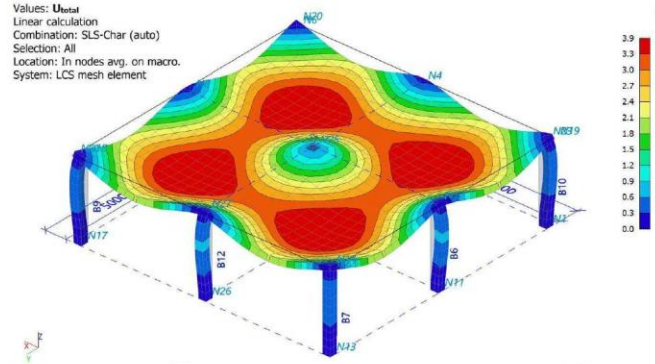
Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic stress

Mesh	x [m]	y [m]	z [m]	Case	σ_{x+} [MPa]	σ_{x-} [MPa]	σ_{y+} [MPa]	σ_{y-} [MPa]	τ_{xy+} [MPa]	τ_{xy-} [MPa]	τ_{xz} [MPa]	τ_{yz} [MPa]
Element: 75; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**-7.9**	**8.0**	6.3	-6.5	0.0	0.0	2.5	0.0
Element: 120; Node: 12	5.000	5.000	3.000	SLS-Char (auto)/1	**21.3**	**-21.3**	16.6	-16.7	0.0	0.0	0.0	2.4
Element: 58; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	6.3	-6.5	**-7.9**	**8.0**	0.0	0.0	0.0	-2.5
Element: 121; Node: 12	5.000	5.000	3.000	SLS-Char (auto)/1	16.6	-16.7	**21.3**	**-21.3**	0.0	0.0	-2.4	0.0
Element: 61; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	8.1	-8.2	8.4	-8.6	**4.8**	**-5.1**	-0.8	-0.9
Element: 78; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	8.4	-8.6	8.1	-8.2	**-4.8**	**5.1**	0.9	-0.8
Element: 119; Node: 8	0.150	5.000	3.000	SLS-Char (auto)/1	20.0	-21.3	17.2	-17.5	0.0	0.0	**-8.1**	0.0
Element: 118; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	20.0	-21.3	17.2	-17.5	0.0	0.0	**8.1**	0.0
Element: 117; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	17.2	-17.5	20.0	-21.3	0.0	0.0	0.0	**-8.1**
Element: 124; Node: 13	5.000	9.850	3.000	SLS-Char (auto)/1	17.2	-17.5	20.0	-21.3	0.0	0.0	0.0	**8.1**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

3.2.2.3. 3D displacement; U_total

Values: U_{total}
Linear calculation
Combination: SLS-Char (auto)
Selection: All
Location: In nodes avg. on macro.
System: LCS mesh element



4. Model 200mm

4.1. Berekening

4.1.1. Mesh setup

Name	Mesh0.05M
Generation of nodes in connections of beam elements	✗
Elastic mesh	✓
Use automatic mesh refinement	✗
Connect members/nodes	✓
Division on haunches and arbitrary members	5
Division for integration strip and 2D-1D upgrade	50
Average number of 1D mesh elements on straight 1D members	1
Average size of 2D mesh element [m]	0.200
Minimal length of beam element [m]	0.100
Maximal length of beam element [m]	1000.000
Average size of tendons, elements on subsoil, nonlinear soil spring [m]	1.000
Maximal out of plane angle of a quadrilateral [mrad]	30.0
Minimal distance between definition point and line [m]	0.001
Average size of panel element [m]	0.500
Definition of mesh element size for panels	Manual

4.1.2. Berekeningsverslag lineair

Linear calculation

Number of 2D elements	2500
Number of 1D elements	9
Number of mesh nodes	2610
Number of equations	15660
Bending theory	Kirchhoff
Load cases	Self weight, Additional load

Sum of loads and reactions

Load case	Value	X [kN]	Y [kN]	Z [kN]
Self weight	loads	0.00	0.00	-550.10
	reaction in nodes	0.00	0.00	550.10
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00
Additional load	loads	0.00	0.00	-1000.00
	reaction in nodes	0.00	0.00	1000.00
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00

4.2. Resultaten

4.2.1. Reacties

4.2.1.1. 1D internal forces

Linear calculation
Combination: SLS-Char (auto)
Coordinate system: Principal
Extreme 1D: Global
Selection: All

Name	dx [m]	Case	N [kN]	V_y [kN]	V_z [kN]	M_x [kNm]	M_y [kNm]	M_z [kNm]
B11	0.000	SLS-Char (auto)/1	**-487.16**	0.00	0.00	0.00	0.00	0.00
B3	3.000	SLS-Char (auto)/2	**-24.56**	3.64	3.64	**0.00**	7.35	7.35
B6	3.000	SLS-Char (auto)/1	-177.85	0.00	**-18.93**	0.00	**-38.16**	0.00
B4	3.000	SLS-Char (auto)/1	-177.85	0.00	**18.93**	0.00	**38.16**	0.00
B12	3.000	SLS-Char (auto)/1	-177.85	**-18.93**	0.00	0.00	0.00	**-38.16**
B2	3.000	SLS-Char (auto)/1	-177.85	**18.93**	0.00	0.00	0.00	**38.16**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load
SLS-Char (auto)/2	Self weight

4.2.2. Resultaten 2D-elementen

4.2.2.1. 2D internal forces

Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic magnitudes

Mesh	x [m]	y [m]	z [m]	Case	m_x [kNm/m]	m_y [kNm/m]	m_{xy} [kNm/m]	v_x [kN/m]	v_y [kN/m]
Element: 2498; Node: 12	5.000	5.000	3.000	SLS-Char (auto)/1	**-165.33**	**-165.33**	2.56	717.04	-717.04
Element: 85; Node: 11	0.150	0.150	3.000	SLS-Char (auto)/1	**79.16**	**79.16**	53.76	1121.62	1121.62
Element: 85; Node: 1	0.000	0.000	3.000	SLS-Char (auto)/1	-107.34	-107.34	**-90.78**	**1868.13**	**1868.13**
Element: 104; Node: 2	10.000	0.000	3.000	SLS-Char (auto)/1	-107.34	-107.34	**90.78**	**-1868.13**	1868.13
Element: 123; Node: 3	10.000	10.000	3.000	SLS-Char (auto)/1	-107.34	-107.34	-90.78	-1868.13	**-1868.13**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

4.2.2.2. 2D stress/strain

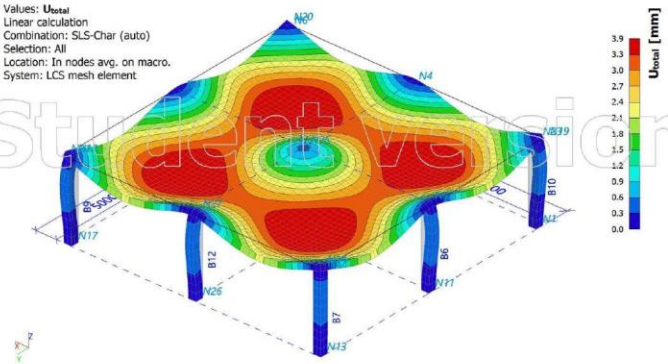
Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic stress

Mesh	x [m]	y [m]	z [m]	Case	σ_{x+} [MPa]	σ_{x-} [MPa]	σ_{y+} [MPa]	σ_{y-} [MPa]	τ_{xy+} [MPa]	τ_{xy-} [MPa]	τ_{xz} [MPa]	τ_{yz} [MPa]
Element: 85; Node: 11	0.150	0.150	3.000	SLS-Char (auto)/1	**-11.7**	**12.1**	**-11.7**	**12.1**	-7.9	8.3	-8.4	-8.4
Element: 2497; Node: 12	5.000	5.000	3.000	SLS-Char (auto)/1	**24.8**	**-24.8**	**24.8**	**-24.8**	0.4	-0.4	5.4	5.4
Element: 104; Node: 2	10.000	0.000	3.000	SLS-Char (auto)/1	15.9	-16.3	15.9	-16.3	**-13.6**	**13.6**	**14.0**	-14.0
Element: 85; Node: 1	0.000	0.000	3.000	SLS-Char (auto)/1	15.9	-16.3	15.9	-16.3	13.6	-13.6	**-14.0**	**-14.0**
Element: 123; Node: 3	10.000	10.000	3.000	SLS-Char (auto)/1	15.9	-16.3	15.9	-16.3	**13.6**	**-13.6**	14.0	**14.0**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

4.2.2.3. 3D displacement; U_total

Values: U_{total}
Linear calculation
Combination: SLS-Char (auto)
Selection: All
Location: In nodes avg. on macro.
System: LCS mesh element



5. Model 100mm

5.1. Berekening

5.1.1. Mesh setup

Name	Mesh0.05M
Generation of nodes in connections of beam elements	✗
Elastic mesh	✓
Use automatic mesh refinement	✗
Connect members/nodes	✓
Division on haunches and arbitrary members	5
Division for integration strip and 2D-1D upgrade	50
Average number of 1D mesh elements on straight 1D members	1
Average size of 2D mesh element [m]	0.100
Minimal length of beam element [m]	0.100
Maximal length of beam element [m]	1000.000
Average size of tendons, elements on subsoil, nonlinear soil spring [m]	1.000
Maximal out of plane angle of a quadrilateral [mrad]	30.0
Minimal distance between definition point and line [m]	0.001
Average size of panel element [m]	0.500
Definition of mesh element size for panels	Manual

5.1.2. Berekeningsverslag lineair

Linear calculation

Number of 2D elements	10020
Number of 1D elements	9
Number of mesh nodes	10218
Number of equations	61308
Bending theory	Kirchhoff
Load cases:	Self weight, Additional load

Sum of loads and reactions

Load case	Value	X [kN]	Y [kN]	Z [kN]
Self weight	loads	0.00	0.00	-550.10
	reaction in nodes	0.00	0.00	550.10
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00
Additional load	loads	0.00	0.00	-1000.00
	reaction in nodes	0.00	0.00	1000.00
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00

5.2. Resultaten

5.2.1. Reacties

5.2.1.1. 1D internal forces

Linear calculation
Combination: SLS-Char (auto)
Coordinate system: Principal
Extreme 1D: Global
Selection: All

Name	dx [m]	Case	N [kN]	V_y [kN]	V_z [kN]	M_x [kNm]	M_y [kNm]	M_z [kNm]
B11	0.000	SLS-Char (auto)/1	**-488.57**	0.00	0.00	0.00	0.00	0.00
B3	3.000	SLS-Char (auto)/2	**-24.50**	3.59	3.59	**0.00**	7.23	7.23
B6	3.000	SLS-Char (auto)/1	-177.68	0.00	**-18.41**	0.00	**-37.12**	0.00
B4	3.000	SLS-Char (auto)/1	-177.68	0.00	**18.41**	0.00	**37.12**	0.00
B12	3.000	SLS-Char (auto)/1	-177.68	**-18.41**	0.00	0.00	0.00	**-37.12**
B2	3.000	SLS-Char (auto)/1	-177.68	**18.41**	0.00	0.00	0.00	**37.12**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load
SLS-Char (auto)/2	Self weight

5.2.2. Resultaten 2D-elementen

5.2.2.1. 2D internal forces

Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic magnitudes

Mesh	x [m]	y [m]	z [m]	Case	m_x [kNm/m]	m_y [kNm/m]	m_{xy} [kNm/m]	v_x [kN/m]	v_y [kN/m]
Element: 85; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**-346.76**	-223.67	2.65	-6632.82	-3777.87
Element: 82; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	**191.41**	112.48	-101.93	-8466.39	1983.49
Element: 78; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	-223.67	**-346.76**	2.65	3777.87	6632.82
Element: 81; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	112.48	**191.41**	-101.93	-1983.49	8466.39
Element: 100; Node: 10	9.850	9.850	3.000	SLS-Char (auto)/1	-219.60	-203.34	**-105.79**	**-9006.36**	-2000.47
Element: 94; Node: 9	0.150	9.850	3.000	SLS-Char (auto)/1	-219.60	-203.34	105.79	**9006.36**	-2000.47
Element: 93; Node: 9	0.150	9.850	3.000	SLS-Char (auto)/1	-203.34	-219.60	105.79	2000.47	**-9006.36**
Element: 83; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	-203.34	-219.60	**105.79**	-2000.47	**9006.36**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

5.2.2.2. 2D stress/strain

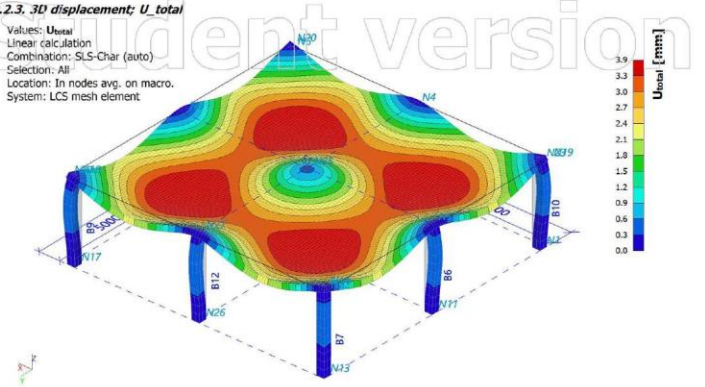
Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic stress

Mesh	x [m]	y [m]	z [m]	Case	σ_{x+} [MPa]	σ_{x-} [MPa]	σ_{y+} [MPa]	σ_{y-} [MPa]	τ_{xy+} [MPa]	τ_{xy-} [MPa]	τ_{xz} [MPa]	τ_{yz} [MPa]
Element: 82; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	**-27.8**	**29.6**	-16.8	16.9	14.9	-15.6	63.5	-14.9
Element: 85; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**51.1**	**-53.0**	33.4	-33.7	-0.8	0.0	49.7	28.3
Element: 81; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	-16.8	16.9	**-27.8**	**29.6**	14.9	-15.6	14.9	-63.5
Element: 78; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	33.4	-33.7	**51.1**	**-53.0**	-0.8	0.0	-28.3	-49.7
Element: 100; Node: 10	9.850	9.850	3.000	SLS-Char (auto)/1	31.9	-34.0	30.3	-30.7	**15.4**	**-16.3**	**67.5**	15.0
Element: 94; Node: 9	0.150	9.850	3.000	SLS-Char (auto)/1	31.9	-34.0	30.3	-30.7	-15.4	16.3	**-67.5**	15.0
Element: 83; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	30.3	-30.7	31.9	-34.0	**-15.4**	**16.3**	15.0	**-67.5**
Element: 93; Node: 9	0.150	9.850	3.000	SLS-Char (auto)/1	30.3	-30.7	31.9	-34.0	-15.4	16.3	-15.0	**67.5**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

5.2.2.3. 3D displacement; U_total

Values: U_{total}
Linear calculation
Combination: SLS-Char (auto)
Selection: All
Location: In nodes avg. on macro.
System: LCS mesh element



Student version

6. Model 50mm

6.1. Berekening

6.1.1. Mesh setup

Name	Mesh0.05M
Generation of nodes in connections of beam elements	✗
Elastic mesh	✓
Use automatic mesh refinement	✗
Connect members/nodes	✓
Division on haunches and arbitrary members	5
Division for integration strip and 2D-1D upgrade	50
Average number of 1D mesh elements on straight 1D members	1
Average size of 2D mesh element [m]	0.050
Minimal length of beam element [m]	0.100
Maximal length of beam element [m]	1000.000
Average size of tendons, elements on subsoil, nonlinear soil spring [m]	1.000
Maximal out of plane angle of a quadrilateral [mrad]	30.0
Minimal distance between definition point and line [m]	0.001
Average size of panel element [m]	0.500
Definition of mesh element size for panels	Manual

6.1.2. Berekeningsverslag lineair

Linear calculation

Number of 2D elements	40000
Number of 1D elements	9
Number of mesh nodes	40410
Number of equations	242460
Bending theory	Kirchhoff
Load cases	Self weight; Additional load

Sum of loads and reactions

Load case	Value	X [kN]	Y [kN]	Z [kN]
Self weight	loads	0.00	0.00	-550.10
	reaction in nodes	0.00	0.00	550.10
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00
Additional load	loads	0.00	0.00	-1000.00
	reaction in nodes	0.00	0.00	1000.00
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00

6.2. Resultaten

6.2.1. Reacties

6.2.1.1. 1D internal forces

Linear calculation
Combination: SLS-Char (auto)
Coordinate system: Principal
Extreme 1D: Global
Selection: All

Name	dx [m]	Case	N [kN]	V_y [kN]	V_z [kN]	M_x [kNm]	M_y [kNm]	M_z [kNm]
B11	0.000	SLS-Char (auto)/1	**-490.68**	0.00	0.00	0.00	0.00	0.00
B3	3.000	SLS-Char (auto)/2	**-24.39**	3.47	3.47	**0.00**	7.00	7.00
B6	3.000	SLS-Char (auto)/1	-177.51	0.00	**-17.62**	0.00	**-35.54**	0.00
B4	3.000	SLS-Char (auto)/1	-177.51	0.00	**17.62**	0.00	**35.54**	0.00
B12	3.000	SLS-Char (auto)/1	-177.51	**-17.62**	0.00	0.00	0.00	**-35.54**
B2	3.000	SLS-Char (auto)/1	-177.51	**17.62**	0.00	0.00	0.00	**35.54**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load
SLS-Char (auto)/2	Self weight

6.2.2. Resultaten 2D-elementen

6.2.2.1. 2D internal forces

Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic magnitudes

Mesh	x [m]	y [m]	z [m]	Case	m_x [kNm/m]	m_y [kNm/m]	m_{xy} [kNm/m]	v_x [kN/m]	v_y [kN/m]
Element: 39973; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**-454.30**	-208.41	-5.79	-11895.82	-10012.83
Element: 39974; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**289.13**	28.04	25.86	-9774.16	7905.91
Element: 39967; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	-208.41	**-454.30**	-5.79	10012.83	11895.82
Element: 39965; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	28.04	**289.13**	25.86	7905.91	9774.16
Element: 39981; Node: 9	0.150	9.850	3.000	SLS-Char (auto)/1	-327.65	-327.65	**137.58**	**12264.09**	-12264.09
Element: 39985; Node: 10	9.850	9.850	3.000	SLS-Char (auto)/1	-327.65	-327.65	**-137.58**	**-12264.09**	**-12264.09**
Element: 39972; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	-327.65	-327.65	137.58	-12264.09	**12264.09**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

6.2.2.2. 2D stress/strain

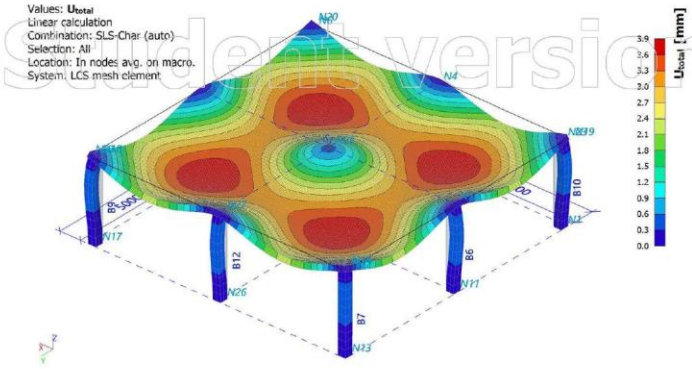
Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic stress

Mesh	x [m]	y [m]	z [m]	Case	σ_{x+} [MPa]	σ_{x-} [MPa]	σ_{y+} [MPa]	σ_{y-} [MPa]	τ_{xy+} [MPa]	τ_{xy-} [MPa]	τ_{xz} [MPa]	τ_{yz} [MPa]
Element: 39974; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**-42.6**	**44.2**	-4.1	4.3	3.2	-4.6	73.3	-59.3
Element: 39976; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**67.1**	**-69.2**	31.0	-31.5	-0.2	1.6	89.2	-75.1
Element: 39999; Node: 13	5.000	9.850	3.000	SLS-Char (auto)/1	-4.1	4.3	**-42.6**	**44.2**	3.2	-4.6	-59.3	73.3
Element: 39967; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	31.0	-31.5	**67.1**	**-69.2**	0.2	-1.6	-75.1	-89.2
Element: 39985; Node: 10	9.850	9.850	3.000	SLS-Char (auto)/1	48.4	-49.9	48.4	-49.9	**19.8**	**-21.5**	**92.0**	**92.0**
Element: 39981; Node: 9	0.150	9.850	3.000	SLS-Char (auto)/1	48.4	-49.9	48.4	-49.9	**-19.8**	**21.5**	**-92.0**	92.0
Element: 39972; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	48.4	-49.9	48.4	-49.9	-19.8	21.5	92.0	**-92.0**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

6.2.2.3. 3D displacement; U_total

Values: U_{total}
Linear calculation
Combination: SLS-Char (auto)
Selection: All
Location: In nodes avg. on macro.
System: LCS mesh element



7. Model 25mm

7.1. Berekening

7.1.1. Mesh setup

Name	Mesh0.05M
Generation of nodes in connections of beam elements	✗
Elastic mesh	✓
Use automatic mesh refinement	✗
Connect members/nodes	✓
Division on haunches and arbitrary members	5
Division for integration strip and 2D-1D upgrade	50
Average number of 1D mesh elements on straight 1D members	1
Average size of 2D mesh element [m]	0.025
Minimal length of beam element [m]	0.100
Maximal length of beam element [m]	1000.000
Average size of tendons, elements on subsoil, nonlinear soil spring [m]	1.000
Maximal out of plane angle of a quadrilateral [mrad]	30.0
Minimal distance between definition point and line [m]	0.001
Average size of panel element [m]	0.500
Definition of mesh element size for panels	Manual

7.1.2. Berekeningsverslag lineair

Linear calculation

Number of 2D elements	160000
Number of 1D elements	9
Number of mesh nodes	160810
Number of equations	964860
Bending theory	Kirchhoff
Load cases	Self weight; Additional load

Sum of loads and reactions

Load case	Value	X [kN]	Y [kN]	Z [kN]
Self weight	loads	0.00	0.00	-550.10
	reaction in nodes	0.00	0.00	550.10
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00
Additional load	loads	0.00	0.00	-1000.00
	reaction in nodes	0.00	0.00	1000.00
	reaction on lines	0.00	0.00	0.00
	contact 1D	0.00	0.00	0.00
	contact 2D	0.00	0.00	0.00

7.2. Resultaten

7.2.1. Reacties

7.2.1.1. 1D internal forces

Linear calculation
Combination: SLS-Char (auto)
Coordinate system: Principal
Extreme 1D: Global
Selection: All

Student version

Name	dx [m]	Case	N [kN]	V_y [kN]	V_z [kN]	M_x [kNm]	M_y [kNm]	M_z [kNm]
B11	0.000	SLS-Char (auto)/1	**-492.11**	0.00	0.00	0.00	0.00	0.00
B3	3.000	SLS-Char (auto)/2	**-24.30**	3.38	3.38	**0.00**	6.82	6.82
B6	3.000	SLS-Char (auto)/1	-177.42	0.00	**-17.08**	0.00	**-34.45**	0.00
B4	3.000	SLS-Char (auto)/1	-177.42	0.00	**17.08**	0.00	**34.45**	0.00
B12	3.000	SLS-Char (auto)/1	-177.42	**-17.08**	0.00	0.00	0.00	**-34.45**
B2	3.000	SLS-Char (auto)/1	-177.42	**17.08**	0.00	0.00	0.00	**34.45**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load
SLS-Char (auto)/2	Self weight

7.2.2. Resultaten 2D-elementen

7.2.2.1. 2D internal forces

Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic magnitudes

Mesh	x [m]	y [m]	z [m]	Case	m_x [kNm/m]	m_y [kNm/m]	m_{xy} [kNm/m]	v_x [kN/m]	v_y [kN/m]
Element: 159973; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**-808.54**	-337.51	-17.72	44032.89	-36815.29
Element: 159974; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**621.78**	131.85	39.10	-39796.53	32611.35
Element: 159967; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	-337.51	**-808.54**	-17.72	36845.29	44032.89
Element: 159966; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	131.85	**621.78**	-39.10	-32611.35	39796.53
Element: 159985; Node: 10	9.850	9.850	3.000	SLS-Char (auto)/1	-610.62	-610.62	**-256.33**	-46986.16	-46986.17
Element: 159972; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	-610.62	-610.62	**256.33**	**-46986.17**	**46986.16**
Element: 159981; Node: 9	0.150	9.850	3.000	SLS-Char (auto)/1	-610.62	-610.62	256.33	**46986.17**	**-46986.17**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

7.2.2.2. 2D stress/strain

Linear calculation
Combination: SLS-Char (auto)
Extreme: Global
Selection: All
Filter: Thickness = 200.00 mm
Location: In nodes avg. on macro. System: LCS mesh element
Basic stress

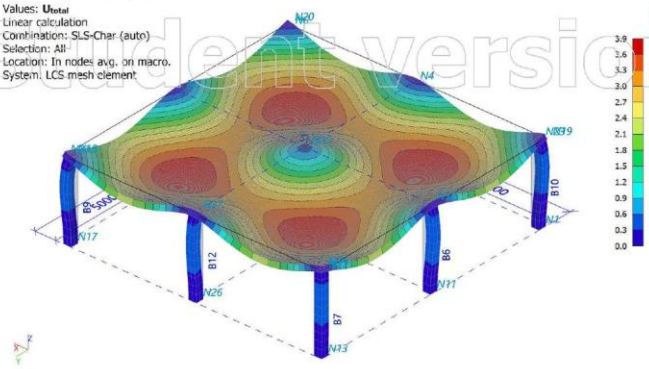
Student version

Mesh	x [m]	y [m]	z [m]	Case	σ_{x+} [MPa]	σ_{x-} [MPa]	σ_{y+} [MPa]	σ_{y-} [MPa]	τ_{xy+} [MPa]	τ_{xy-} [MPa]	τ_{xz} [MPa]	τ_{yz} [MPa]
Element: 159974; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**-91.6**	**94.9**	-19.5	20.1	4.5	-7.3	298.5	-244.6
Element: 159973; Node: 7	9.850	5.000	3.000	SLS-Char (auto)/1	**119.4**	**-123.2**	50.2	-51.1	1.3	-4.0	330.2	276.3
Element: 159966; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	-19.5	20.1	**-91.6**	**94.9**	4.5	-7.3	244.6	-298.5
Element: 159967; Node: 5	5.000	0.150	3.000	SLS-Char (auto)/1	50.2	-51.1	**119.4**	**-123.2**	1.3	-4.0	-276.3	-330.2
Element: 159985; Node: 10	9.850	9.850	3.000	SLS-Char (auto)/1	90.2	-93.0	90.2	-93.0	**36.8**	**-40.1**	**352.4**	352.4
Element: 159981; Node: 9	0.150	9.850	3.000	SLS-Char (auto)/1	90.2	-93.0	90.2	-93.0	**-36.8**	**40.1**	**-352.4**	**352.4**
Element: 159972; Node: 6	9.850	0.150	3.000	SLS-Char (auto)/1	90.2	-93.0	90.2	-93.0	-36.8	40.1	352.4	**-352.4**

Name	Combination key
SLS-Char (auto)/1	Self weight + Additional load

7.2.2.3. 3D displacement; U_total

Values: U_{total}
Linear calculation
Combination: SLS-Char (auto)
Selection: All
Location: In nodes avg. on macro.
System: LCS mesh element



Appendix D: ANSYS Moment Calculation + Mesh pictures

400 mm

			X Axis	Y Axis	Z Axis
dz [mm]	Position [mm]	Length [mm]	Stress [MPa]	Total [MPa]	Total [MPa]
4.17	-100	0.00	-7.26	-8.34	-10.40
4.17	-96	4.17	-6.95	-7.71	-9.52
4.17	-92	8.33	-6.66	-7.09	-8.70
4.17	-88	12.50	-6.36	-6.48	-7.87
4.17	-83	16.67	-6.05	-5.87	-7.06
4.17	-79	20.83	-5.74	-5.27	-6.26
4.17	-75	25.00	-5.43	-4.66	-5.48
4.17	-71	29.17	-5.11	-4.07	-4.71
4.17	-67	33.33	-4.79	-3.48	-3.95
4.17	-63	37.50	-4.45	-3.10	-3.86
4.17	-58	41.67	-4.11	-2.73	-3.76
4.17	-54	45.83	-3.84	-2.49	-3.80
4.17	-50	50.00	-3.61	-2.32	-3.94
4.17	-46	54.17	-3.29	-2.11	-3.74
4.17	-42	58.33	-2.97	-1.91	-3.57
4.17	-38	62.50	-2.64	-1.70	-3.39
4.17	-33	66.67	-2.32	-1.49	-3.21
4.17	-29	70.83	-1.99	-1.28	-3.04
4.17	-25	75.00	-1.66	-1.07	-2.87
4.17	-21	79.17	-1.34	-0.86	-2.70
4.17	-17	83.33	-1.00	-0.64	-2.55
4.17	-13	87.50	-0.67	-0.41	-2.45
4.17	-8	91.67	-0.33	-0.17	-2.35
4.17	-4	95.83	0.01	0.07	-2.25
4.17	0	100.00	0.35	0.30	-2.15
4.16	4	104.17	0.69	0.54	-2.04
4.17	8	108.33	1.03	0.78	-1.94
4.17	13	112.50	1.36	1.01	-1.84
4.16	17	116.67	1.70	1.25	-1.74
4.17	21	120.83	2.04	1.49	-1.64
4.17	25	125.00	2.38	1.72	-1.54
4.16	29	129.17	2.72	1.96	-1.44
4.17	33	133.33	3.06	2.20	-1.34
4.17	38	137.50	3.39	2.43	-1.24
4.16	42	141.67	3.73	2.67	-1.14
4.17	46	145.83	4.07	2.91	-1.04
4.17	50	150.00	4.41	3.14	-0.94
4.16	54	154.17	4.75	3.38	-0.84
4.17	58	158.33	5.09	3.61	-0.74
4.17	63	162.50	5.43	3.85	-0.65
4.16	67	166.67	5.76	4.09	-0.55
4.17	71	170.83	6.10	4.32	-0.45
4.17	75	175.00	6.44	4.56	-0.35
4.16	79	179.17	6.78	4.80	-0.25
4.17	83	183.33	7.12	5.03	-0.16
4.17	88	187.50	7.46	5.27	-0.06
4.16	92	191.67	7.79	5.51	0.05
4.17	96	195.83	8.14	5.74	0.12
0.00	100	200.00	8.48	5.97	0.17
		Moments	**-52.58**	**-42.37**	**-27.49**

Table D.1: Moment calculation 400mm

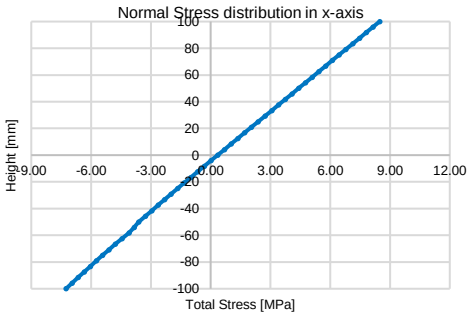


Figure D.2: Normal stress distribution around X-axis 400 mm

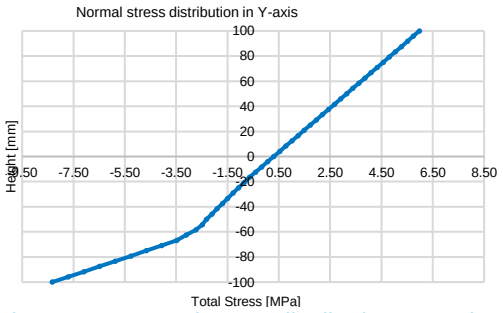


Figure D.3: Normal stress distribution around Y-axis 400mm

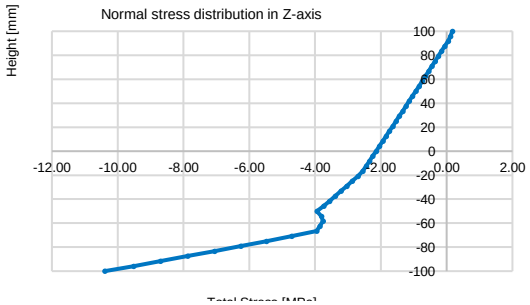


Figure D.1: Normal stress distribution around Z-axis 400mm

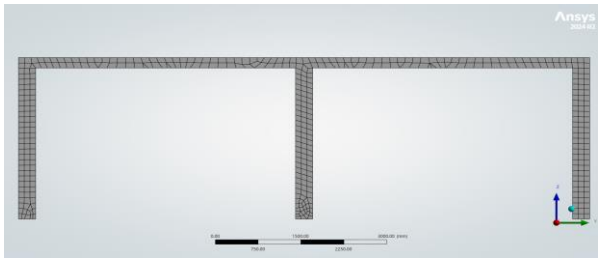


Figure D.5: Side profile mesh 400mm

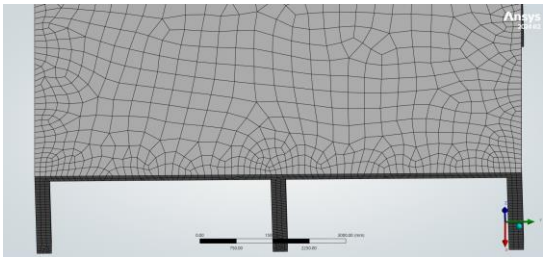


Figure D.5: Top profile mesh 400mm

200 mm

			X Axis	Y Axis	Z Axis
dz [mm]	Position [mm]	Length [mm]	Total [MPa]	Total [MPa]	Total [MPa]
4.17	-100	0.00	-8.04	-9.63	-11.05
4.17	-96	4.17	-7.67	-8.91	-10.46
4.17	-92	8.33	-7.29	-8.20	-9.87
4.17	-88	12.50	-6.91	-7.49	-9.28
4.17	-83	16.67	-6.53	-6.78	-8.69
4.17	-79	20.83	-6.16	-6.07	-8.11
4.17	-75	25.00	-5.78	-5.36	-7.52
4.17	-71	29.17	-5.40	-4.65	-6.93
4.17	-67	33.33	-5.03	-3.94	-6.34
4.17	-63	37.50	-4.65	-3.23	-5.76
4.17	-58	41.67	-4.27	-2.52	-5.17
4.17	-54	45.83	-3.92	-2.11	-4.60
4.17	-50	50.00	-3.58	-1.97	-4.11
4.17	-46	54.17	-3.25	-1.83	-3.62
4.17	-42	58.33	-2.92	-1.70	-3.13
4.17	-38	62.50	-2.59	-1.56	-2.64
4.17	-33	66.67	-2.25	-1.42	-2.15
4.17	-29	70.83	-1.92	-1.23	-1.89
4.17	-25	75.00	-1.60	-0.98	-1.87
4.17	-21	79.17	-1.27	-0.73	-1.85
4.17	-17	83.33	-0.94	-0.48	-1.82
4.17	-13	87.50	-0.62	-0.23	-1.80
4.17	-8	91.67	-0.30	0.01	-1.76
4.17	-4	95.83	0.01	0.19	-1.66
4.17	0	100.00	0.33	0.37	-1.58
4.16	4	104.17	0.65	0.56	-1.51
4.17	8	108.33	0.97	0.75	-1.45
4.17	13	112.50	1.30	0.94	-1.39
4.16	17	116.67	1.62	1.15	-1.34
4.17	21	120.83	1.89	1.38	-1.27
4.17	25	125.00	2.15	1.60	-1.18
4.16	29	129.17	2.53	1.73	-1.29
4.17	33	133.33	2.90	1.99	-1.22
4.17	38	137.50	3.26	2.26	-1.14
4.16	42	141.67	3.62	2.53	-1.06
4.17	46	145.83	3.98	2.81	-0.98
4.17	50	150.00	4.34	3.08	-0.91
4.16	54	154.17	4.71	3.36	-0.83
4.17	58	158.33	5.07	3.64	-0.76
4.17	63	162.50	5.44	3.92	-0.68
4.16	67	166.67	5.80	4.20	-0.61
4.17	71	170.83	6.17	4.48	-0.54
4.17	75	175.00	6.53	4.76	-0.47
4.16	79	179.17	6.90	5.04	-0.40
4.17	83	183.33	7.27	5.33	-0.34
4.17	88	187.50	7.64	5.61	-0.27
4.16	92	191.67	7.99	5.88	-0.20
4.17	96	195.83	8.34	6.11	-0.13
0.00	100	200.00	8.68	6.34	-0.06
		Moments	**-54.43**	**-45.51**	**-32.23**

Table D.2: Moment calculation 200mm

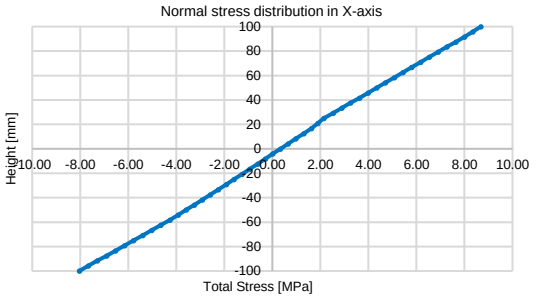


Figure D.8: Normal stress distribution in X-axis 200 mm

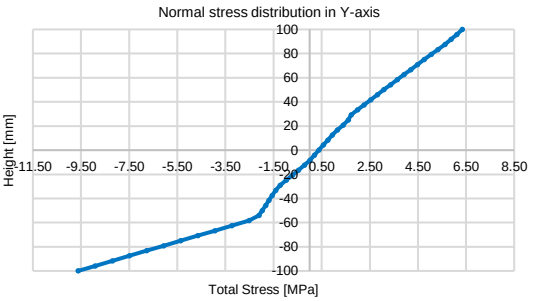


Figure D.7: Normal stress distribution in Y-axis 200 mm

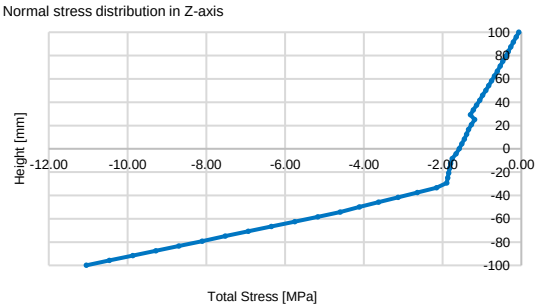


Figure D.6: Normal stress distribution in Z-axis 200 mm

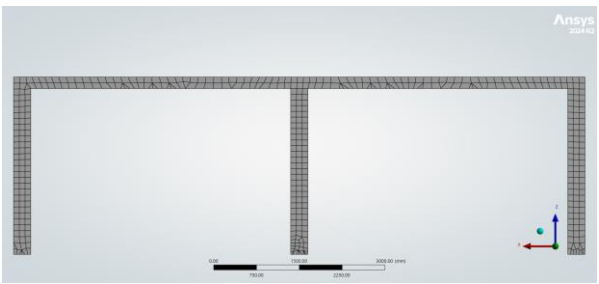


Figure D.10: Side profile mesh 200mm

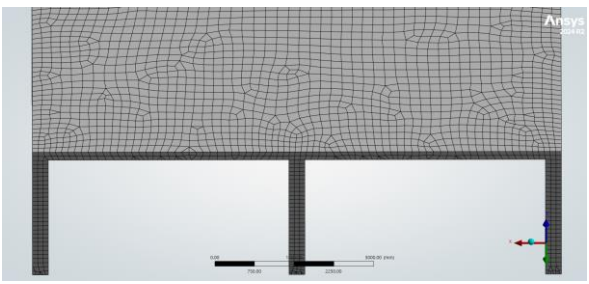


Figure D.9: Top profile mesh 200mm

100 mm

			X Axis	Y Axis	Z Axis
dz [mm]	Position [mm]	Length [mm]	Total [MPa]	Total [MPa]	Total [MPa]
4.17	-100	0.00	-7.3216	-6.9731	-8.2162
4.17	-96	4.17	-7.0017	-6.6344	-7.9503
4.17	-92	8.33	-6.6819	-6.2959	-7.6846
4.17	-88	12.50	-6.3622	-5.9576	-7.4192
4.17	-83	16.67	-6.0426	-5.6195	-7.1539
4.17	-79	20.83	-5.7231	-5.2815	-6.8889
4.17	-75	25.00	-5.4037	-4.9438	-6.6241
4.17	-71	29.17	-5.0844	-4.6062	-6.3595
4.17	-67	33.33	-4.7652	-4.2687	-6.095
4.17	-63	37.50	-4.4461	-3.9314	-5.8308
4.17	-58	41.67	-4.127	-3.5942	-5.5667
4.17	-54	45.83	-3.8081	-3.2572	-5.3027
4.17	-50	50.00	-3.4892	-2.9203	-5.0389
4.17	-46	54.17	-3.1703	-2.5835	-4.7753
4.17	-42	58.33	-2.8516	-2.2469	-4.5118
4.17	-38	62.50	-2.5329	-1.9104	-4.2484
4.17	-33	66.67	-2.2143	-1.5739	-3.9852
4.17	-29	70.83	-1.8957	-1.2376	-3.7221
4.17	-25	75.00	-1.5772	-0.9014	-3.4591
4.17	-21	79.17	-1.2588	-0.56528	-3.1963
4.17	-17	83.33	-0.94037	-0.22926	-2.9335
4.17	-13	87.50	-0.62204	0.10666	-2.6709
4.17	-8	91.67	-0.30377	0.4425	-2.4083
4.17	-4	95.83	1.45E-02	0.77826	-2.1459
4.17	0	100.00	0.33262	1.1139	-1.8836
4.16	4	104.17	0.65653	1.4112	-1.6704
4.17	8	108.33	0.99597	1.6058	-1.5887
4.17	13	112.50	1.3354	1.8003	-1.5071
4.16	17	116.67	1.6748	1.9948	-1.4254
4.17	21	120.83	2.0142	2.1893	-1.3438
4.17	25	125.00	2.3535	2.3838	-1.2622
4.16	29	129.17	2.6929	2.5783	-1.1807
4.17	33	133.33	3.0322	2.7727	-1.0991
4.17	38	137.50	3.3715	2.9672	-1.0176
4.16	42	141.67	3.7108	3.1616	-0.93606
4.17	46	145.83	4.05	3.3561	-0.85456
4.17	50	150.00	4.3893	3.5505	-0.77308
4.16	54	154.17	4.7285	3.7449	-0.69163
4.17	58	158.33	5.0677	3.9394	-0.61019
4.17	63	162.50	5.4069	4.1338	-0.52877
4.16	67	166.67	5.746	4.3282	-0.44738
4.17	71	170.83	6.0852	4.5226	-0.36601
4.17	75	175.00	6.4243	4.717	-0.28466
4.16	79	179.17	6.7634	4.9113	-0.20333
4.17	83	183.33	7.1024	5.1057	-0.12203
4.17	88	187.50	7.4415	5.3001	-4.08E-02
4.16	92	191.67	7.7805	5.4944	4.05E-02
4.17	96	195.83	8.1195	5.6888	0.12172
0.00	100	200.00	8.4585	5.8831	0.20291
		Moments	**-52.37**	**-43.26**	**-29.94**

Table D.3: Moment calculation 100mm

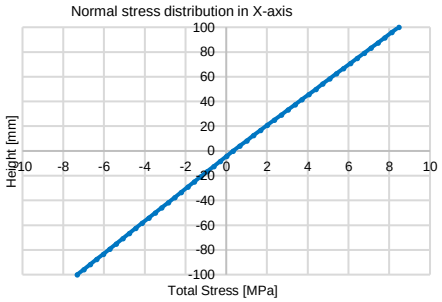


Figure D.11: Normal stress distribution in X-axis 100mm

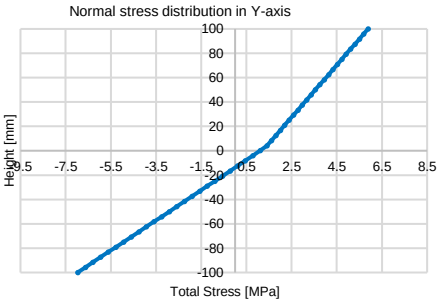


Figure D.12: Normal stress distribution in Y-axis 100mm

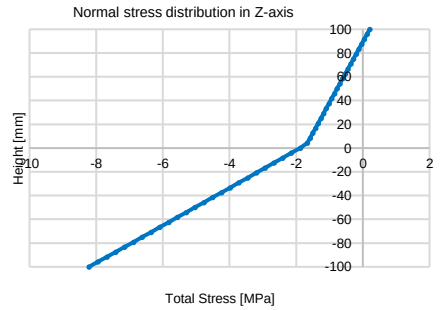


Figure D.13: Normal stress distribution in Z-axis 100mm

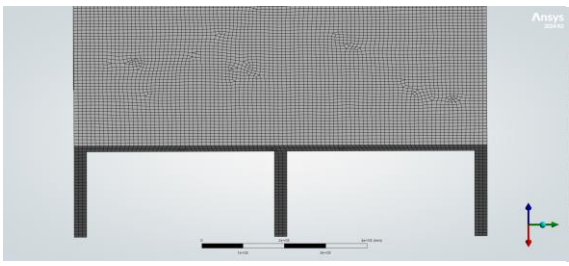


Figure D.14:Top profile mesh 100 mm

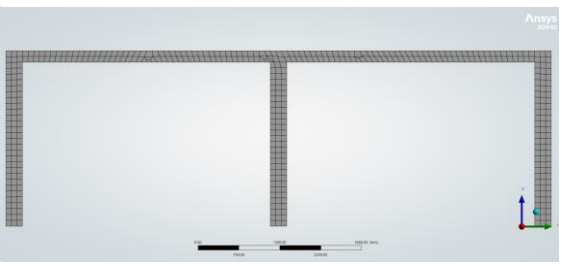


Figure D.15: Side profile mesh 100mm

50 mm

			X Axis	Y Axis	Z Axis
dz [mm]	Position [mm]	Length [mm]	Total [MPa]	Total [MPa]	Total [MPa]
4.17	-100	0.00	**-7.95**	-10.06	-10.49
4.17	-96	4.17	-7.59	-9.36	-10.02
4.17	-92	8.33	-7.20	-8.58	-9.39
4.17	-88	12.50	-6.83	-7.84	-8.83
4.17	-83	16.67	-6.45	-7.10	-8.27
4.17	-79	20.83	-6.08	-6.36	-7.72
4.17	-75	25.00	-5.70	-5.62	-7.17
4.17	-71	29.17	-5.33	-4.88	-6.61
4.17	-67	33.33	-4.95	-4.15	-6.07
4.17	-63	37.50	-4.58	-3.42	-5.52
4.17	-58	41.67	-4.21	-2.69	-4.98
4.17	-54	45.83	-3.84	-1.97	-4.45
4.17	-50	50.00	-3.49	-1.39	-4.00
4.17	-46	54.17	-3.18	-1.26	-3.80
4.17	-42	58.33	-2.87	-1.12	-3.60
4.17	-38	62.50	-2.56	-0.98	-3.40
4.17	-33	66.67	-2.25	-0.84	-3.21
4.17	-29	70.83	-1.94	-0.70	-3.01
4.17	-25	75.00	-1.63	-0.55	-2.81
4.17	-21	79.17	-1.32	-0.40	-2.61
4.17	-17	83.33	-1.01	-0.25	-2.42
4.17	-13	87.50	-0.70	-0.10	-2.22
4.17	-8	91.67	-0.39	0.05	-2.02
4.17	-4	95.83	-0.07	0.22	-1.85
4.17	0	100.00	0.26	0.43	-1.74
4.16	4	104.17	0.59	0.64	-1.64
4.17	8	108.33	0.92	0.85	-1.53
4.17	13	112.50	1.26	1.06	-1.43
4.16	17	116.67	1.59	1.27	-1.32
4.17	21	120.83	1.92	1.48	-1.22
4.17	25	125.00	2.25	1.68	-1.11
4.16	29	129.17	2.59	1.89	-1.01
4.17	33	133.33	2.92	2.10	-0.91
4.17	38	137.50	3.25	2.32	-0.80
4.16	42	141.67	3.58	2.53	-0.70
4.17	46	145.83	3.92	2.74	-0.59
4.17	50	150.00	4.26	2.98	-0.51
4.16	54	154.17	4.61	3.26	-0.46
4.17	58	158.33	4.97	3.54	-0.41
4.17	63	162.50	5.32	3.82	-0.36
4.16	67	166.67	5.68	4.11	-0.31
4.17	71	170.83	6.03	4.39	-0.26
4.17	75	175.00	6.39	4.67	-0.22
4.16	79	179.17	6.75	4.95	-0.17
4.17	83	183.33	7.10	5.24	-0.12
4.17	88	187.50	7.46	5.52	-0.07
4.16	92	191.67	7.81	5.80	-0.02
4.17	96	195.83	8.17	6.08	0.03
0.00	100	200.00	8.52	6.37	0.08
		Moments	**-53.58**	**-45.71**	**-32.72**

Table D.4: Moment calculation 50mm

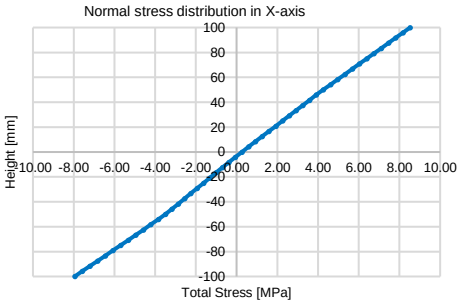


Figure D.17: Normal stress distribution in X-axis 50mm

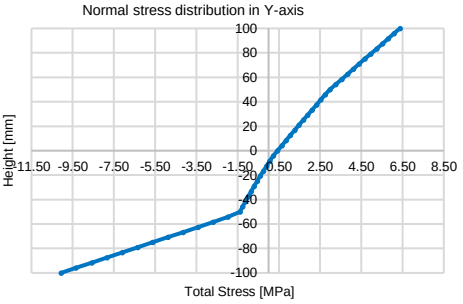


Figure D.16: Normal stress distribution in Y-axis 50mm

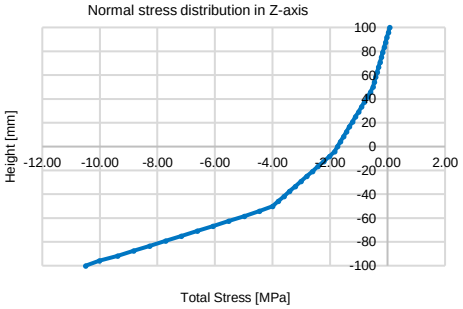


Figure D.18: Normal stress distribution in Z-axis 50mm

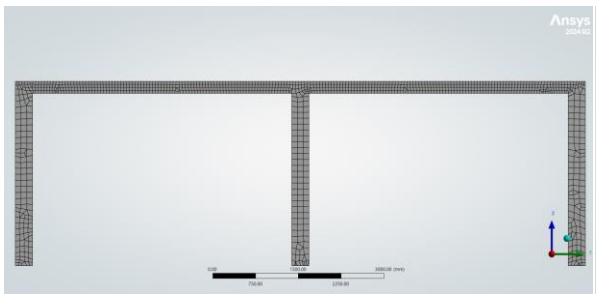


Figure D.19: Side profile mesh 50 mm

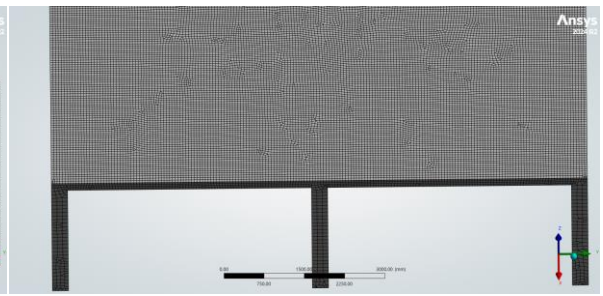


Figure D.20: Top profile mesh 50 mm

25 mm

			X Axis	Y Axis	Z Axis
dz [mm]	Position [mm]	Length [mm]	Total [MPa]	Total [MPa]	Total [MPa]
4.17	-100.00	0.00	-8.97	-12.20	-14.08
4.17	-95.83	4.17	-8.42	-10.80	-12.95
4.17	-91.67	8.33	-7.86	-9.40	-11.82
4.17	-87.50	12.50	-7.31	-8.01	-10.69
4.17	-83.33	16.67	-6.75	-6.61	-9.56
4.17	-79.17	20.83	-6.20	-5.21	-8.43
4.17	-75.00	25.00	-5.64	-3.82	-7.30
4.17	-70.83	29.17	-5.15	-2.71	-6.34
4.17	-66.67	33.33	-4.85	-2.66	-5.87
4.17	-62.50	37.50	-4.55	-2.58	-5.43
4.17	-58.33	41.67	-4.25	-2.48	-5.02
4.17	-54.17	45.83	-3.95	-2.36	-4.61
4.17	-50.00	50.00	-3.65	-2.23	-4.23
4.17	-45.83	54.17	-3.33	-2.03	-3.93
4.17	-41.67	58.33	-3.01	-1.76	-3.76
4.17	-37.50	62.50	-2.69	-1.49	-3.58
4.17	-33.33	66.67	-2.37	-1.22	-3.38
4.17	-29.17	70.83	-2.04	-0.95	-3.14
4.17	-25.00	75.00	-1.72	-0.69	-2.91
4.17	-20.83	79.17	-1.41	-0.47	-2.74
4.17	-16.67	83.33	-1.08	-0.29	-2.53
4.17	-12.50	87.50	-0.75	-0.10	-2.33
4.17	-8.33	91.67	-0.42	0.10	-2.16
4.17	-4.17	95.83	-0.10	0.31	-2.04
4.17	0.00	100.00	0.23	0.52	-1.93
4.16	4.17	104.17	0.56	0.72	-1.80
4.17	8.33	108.33	0.90	0.92	-1.66
4.17	12.50	112.50	1.23	1.11	-1.53
4.16	16.67	116.67	1.56	1.31	-1.39
4.17	20.83	120.83	1.89	1.51	-1.26
4.17	25.00	125.00	2.23	1.71	-1.14
4.16	29.17	129.17	2.57	1.93	-1.04
4.17	33.33	133.33	2.91	2.14	-0.94
4.17	37.50	137.50	3.25	2.36	-0.84
4.16	41.67	141.67	3.60	2.57	-0.74
4.17	45.83	145.83	3.94	2.79	-0.65
4.17	50.00	150.00	4.28	3.01	-0.56
4.16	54.17	154.17	4.64	3.27	-0.49
4.17	58.33	158.33	4.99	3.52	-0.42
4.17	62.50	162.50	5.34	3.78	-0.35
4.16	66.67	166.67	5.69	4.03	-0.28
4.17	70.83	170.83	6.05	4.28	-0.21
4.17	75.00	175.00	6.40	4.55	-0.15
4.16	79.17	179.17	6.77	4.88	-0.12
4.17	83.33	183.33	7.14	5.21	-0.09
4.17	87.50	187.50	7.50	5.53	-0.07
4.16	91.67	191.67	7.87	5.86	-0.04
4.17	95.83	195.83	8.24	6.19	-0.01
0.00	100.00	200.00	8.60	6.52	0.02
		Moment	-55.1	-45.8	-37.8

Table D.5: Moment calculation 25 mm

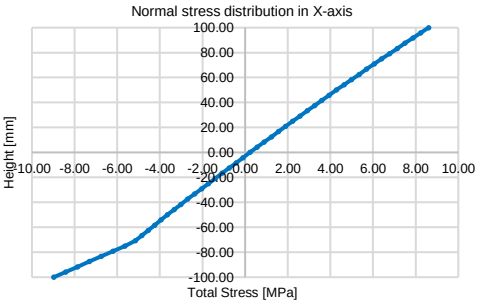


Figure D.23: Normal stress distribution in x-axis

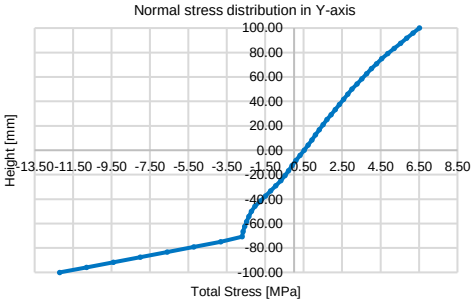


Figure D.22: Normal stress distribution in y-axis

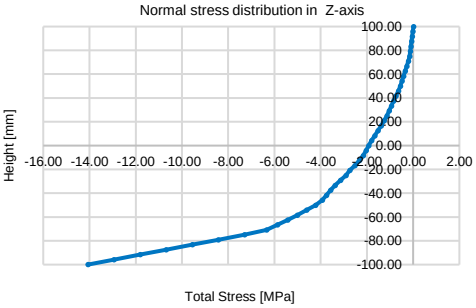


Figure D.21: Normal stress distribution in z-axis

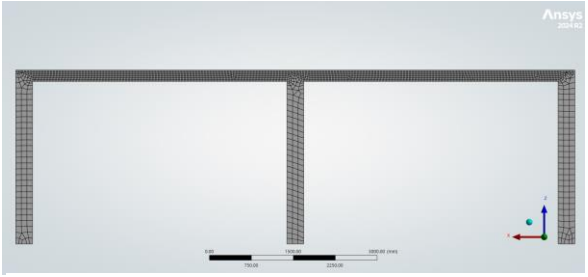


Figure D.24: Side profile mesh 25 mm

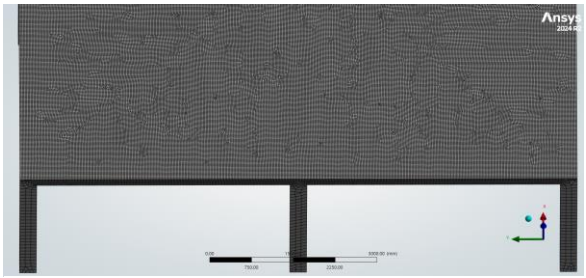


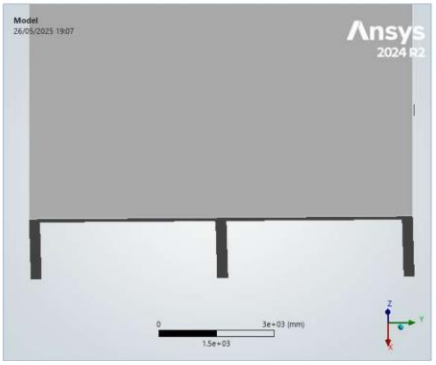
Figure D.25: Top profile mesh 25 mm

Appendix E: ANSYS Reports

Ansys

Project*

Author	Daniel Blanco Blanco
Prepared for	Bachelor Thesis
First Saved	Tuesday, May 13, 2025
Last Saved	Monday, May 26, 2025
Product Version	2024 R2
Save Project Before Solution	No
Save Project After Solution	No



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    - Geometry Import (A3)
  - Geometry
    - SYS\Solid
  - Construction Geometry
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  - Materials
  - Coordinate Systems
  - Mesh
    - Mesh Controls
  - Static Structural (A5)
    - Analysis Settings
    - Standard Earth Gravity
    - Loads
    - Solution (A6)
      - Solution Information
      - Results
      - Probes
- Material Data
  - Concrete 2

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

TABLE 2
Model (A4) > Geometry Imports

Object Name	*Geometry Imports*
State	Solved

TABLE 3
Model (A4) > Geometry Imports > Geometry Import (A3)

Object Name	*Geometry Import (A3)*
State	Solved
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	

Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Geometry

TABLE 4
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	44040
Elements	11716
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes

Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*SYS\Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	Concrete 2
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Centroid X	5000. mm
Centroid Y	5000. mm
Centroid Z	-62.913 mm
Moment of Inertia Ip1	5.2571e+011 kg·mm²
Moment of Inertia Ip2	5.2571e+011 kg·mm²
Moment of Inertia Ip3	1.0176e+012 kg·mm²
Statistics	

Nodes	44040
Elements	11716
Mesh Metric	None
CAD Attributes	
PartTolerance:	0.00000001
SCRootPartComponent	
Color:128,128,255	

TABLE 6
Model (A4) > Construction Geometry

Object Name	*Construction Geometry*
State	Fully Defined
Display	
Show Mesh	No

TABLE 7
Model (A4) > Construction Geometry > Paths

Object Name	*Path*
State	Fully Defined
Definition	
Path Type	Two Points
Path Coordinate System	Global Coordinate System
Number of Sampling Points	47.
Suppressed	No
Start	
Coordinate System	Global Coordinate System
Start X Coordinate	5000. mm
Start Y Coordinate	300. mm
Start Z Coordinate	0. mm
Location	Defined
End	
Coordinate System	Global Coordinate System
End X Coordinate	5000. mm
End Y Coordinate	300. mm
End Z Coordinate	200. mm
Location	Defined

TABLE 8
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	2
Material Assignments	0

Coordinate Systems

TABLE 9
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm

Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]
Transfer Properties	
Source	
Read Only	No

Mesh

TABLE 10
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Nonlinear Mechanical
Element Order	Program Controlled
Element Size	500.0 mm
Sizing	
Growth Rate	Default (1.5)
Max Size	Default (1000.0 mm)
Mesh Defeaturing	Yes
Defeature Size	Default (2.5 mm)
Capture Curvature	Yes
Curvature Min Size	Default (5.0 mm)
Curvature Normal Angle	Default (60.0°)
Capture Proximity	No
Bounding Box Diagonal	14478 mm
Average Surface Area	6.1364e+006 mm²
Minimum Edge Length	300.0 mm
Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.9)
Target Jacobian Ratio (Corner Nodes)	Default (4.e-002)
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
Inflation Element Type	Wedges
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (4.5 mm)
Generate Pinch on Refresh	No
Statistics	
Nodes	44040
Elements	11716
Show Detailed Statistics	No

TABLE 11
Model (A4) > Mesh > Mesh Controls

Object Name	*Hex Dominant Method*	*Face Sizing*	*Face Sizing 2*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body	2 Faces	37 Faces
Definition			
Suppressed	No		
Method	Hex Dominant		
Element Order	Use Global Setting		
Free Face Mesh Type	All Quad		
Control Messages	Yes, Click To Display...		
Type		Element Size	
Element Size		400.0 mm	100.0 mm
Advanced			
Defeature Size		Default (2.5 mm)	
Influence Volume		No	
Growth Rate		Default (1.5)	
Capture Curvature		Yes	
Curvature Normal Angle		Default (60.0°)	
Local Min Size		Default (5.0 mm)	
Capture Proximity		No	

Static Structural (A5)

TABLE 12
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 13
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart	Program Controlled

Points	
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Program Controlled
Output Controls	
Output Selection	None
Stress	Yes
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

TABLE 14
Model (A4) > Static Structural (A5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. mm/s² (ramped)
Y Component	0. mm/s² (ramped)
Z Component	-9806.6 mm/s² (ramped)
Suppressed	No
Direction	-Z Direction

FIGURE 1
Model (A4) > Static Structural (A5) > Standard Earth Gravity

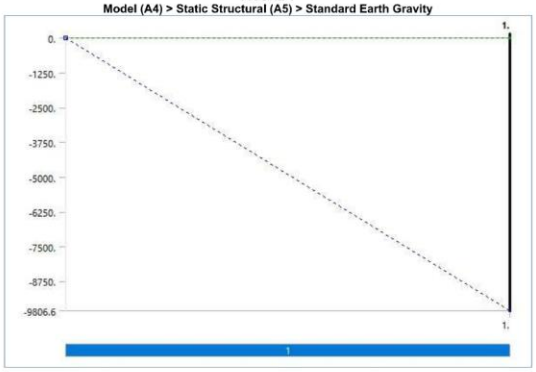


TABLE 15
Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Fixed Support 2*	*Fixed Support 3*	*Fixed Support 4*	*Fixed Support 5*	*Fixed Support 6*	*Fixed Support 7*	*Fixed Support 8*	*Fixed Support 9*	*Force*	*Pressure*
State	Fully Defined									Suppressed	Fully Defined
Scope											
Scoping Method	Geometry Selection										
Geometry	1 Face										
Definition											
Type	Fixed Support									Force	Pressure
Suppressed	No									Yes	No
Define By										Vector	Normal To
Applied By										Surface Effect	
Magnitude										1.e+006 N (ramped)	1.e-002 MPa (ramped)
Direction										Defined	
Loaded Area											Deformed

FIGURE 2
Model (A4) > Static Structural (A5) > Force

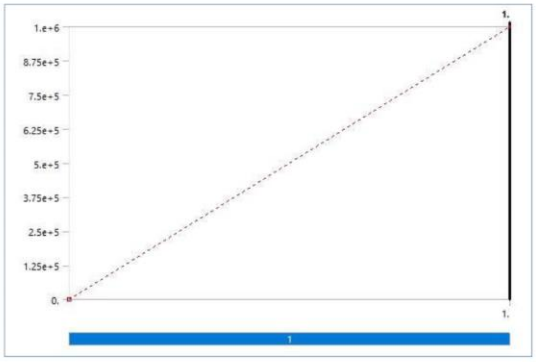
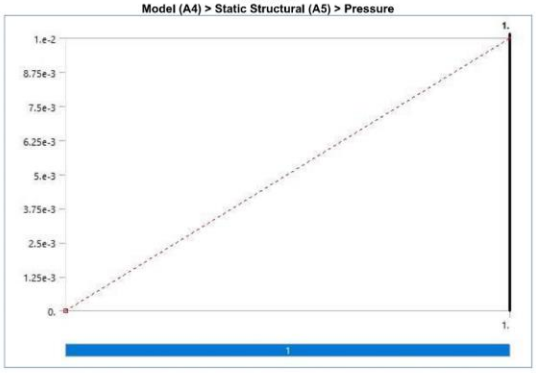


FIGURE 3
Model (A4) > Static Structural (A5) > Pressure



Solution (A6)

TABLE 16
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.

Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	6. s
MAPDL Memory Used	406. MB
MAPDL Result File Size	12.188 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 17
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 18
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*X Stress*	*Y Stress*	*Z Normal Stress*
State	Solved			
Scope				
Scoping Method	Geometry Selection	Path		
Geometry	All Bodies			
Path		Path		
Definition				
Type	Total Deformation	Linearized Normal Stress		
By	Time		Result Set	Time
Display Time	Last			Last
Separate Data by Entity	No			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation		X Axis	Y Axis	Z Axis
Subtype		Total		
Coordinate System		Global Coordinate System		
Zero Through-Thickness Bending Stress		No		
Set Number			Last	
Results				
Minimum	0. mm			
Maximum	3.6733 mm			
Average	1.0422 mm			
Minimum Occurs On	SYS\Solid			
Maximum Occurs On	SYS\Solid			
Total (Inside)		-7.2588 MPa	-8.3354 MPa	-10.397 MPa
Total (Center)		0.34947 MPa	0.30222 MPa	-2.1458 MPa
Total (Outside)		8.4751 MPa	5.9728 MPa	0.172 MPa

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

FIGURE 4
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

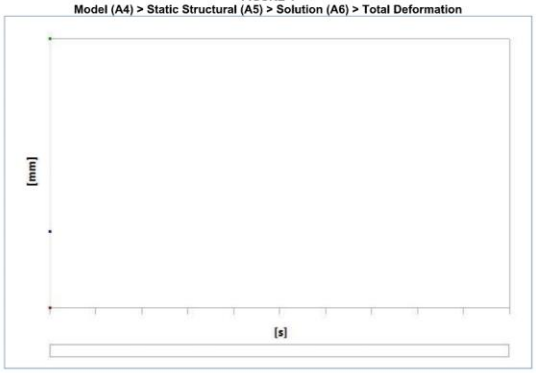


TABLE 19
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.	0.	3.6733	1.0422

FIGURE 5
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

129.17	-1.4403
133.33	-1.3402
137.5	-1.2404
141.67	-1.1407
145.83	-1.0413
150.	-0.94201
154.17	-0.84296
158.33	-0.74413
162.5	-0.64551
166.67	-0.54711
170.83	-0.44893
175.	-0.35097
179.17	-0.25323
183.33	-0.15571
187.5	-5.8422e-002
191.67	4.9268e-002
195.83	0.11765
200.	0.172

TABLE 23
Model (A4) > Static Structural (A5) > Solution (A6) > Probes

Object Name	*Force Reaction*	*Deformation Probe*
State	Solved	
Definition		
Type	Force Reaction	Deformation
Location Method	Boundary Condition	Geometry Selection
Boundary Condition	Fixed Support 5	
Orientation	Global Coordinate System	
Suppressed	No	
Geometry		Defined
X Coordinate		5000.1 mm
Y Coordinate		300.02 mm
Z Coordinate		200. mm
Options		
Result Selection	All	
Display Time	End Time	
Results		
X Axis	-46.046 N	-5.6224e-004 mm
Y Axis	32.719 N	0.17108 mm
Z Axis	4.7998e+005 N	-0.40097 mm
Total	4.7998e+005 N	0.43595 mm
Maximum Value Over Time		
X Axis	-46.046 N	-5.6224e-004 mm
Y Axis	32.719 N	0.17108 mm
Z Axis	4.7998e+005 N	-0.40097 mm
Total	4.7998e+005 N	0.43595 mm
Minimum Value Over Time		
X Axis	-46.046 N	-5.6224e-004 mm
Y Axis	32.719 N	0.17108 mm
Z Axis	4.7998e+005 N	-0.40097 mm
Total	4.7998e+005 N	0.43595 mm
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Force Reaction

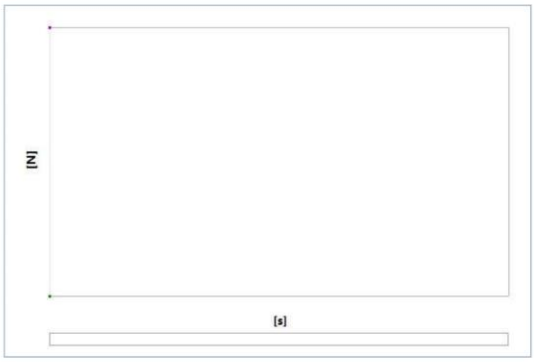


TABLE 24
Model (A4) > Static Structural (A5) > Solution (A6) > Force Reaction

Time [s]	Force Reaction (X) [N]	Force Reaction (Y) [N]	Force Reaction (Z) [N]	Force Reaction (Total) [N]
1.	-46.046	32.719	4.7998e+005	4.7998e+005

FIGURE 9
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

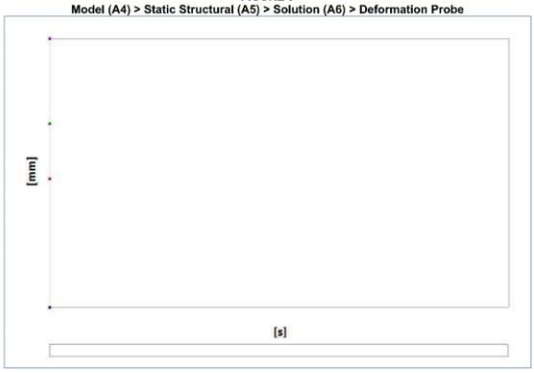


TABLE 25
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

Time	Deformation Probe (X)	Deformation Probe (Y)	Deformation Probe (Z)	Deformation Probe (Total)
[s]	[mm]	[mm]	[mm]	[mm]
1.	-5.6224e-004	0.17108	-0.40097	0.43595

file:///C:/Users/Danie/AppData/Roaming/Ansys/v242/Mechanical_Report/Mechanical_R... 26/05/2025

Material Data

Concrete 2

TABLE 26
Concrete 2 > Constants

Density	2.5e-006 kg mm^-3
Coefficient of Thermal Expansion	1.4e-005 C^-1
Specific Heat	7.8e+005 mJ kg^-1 C^-1
Thermal Conductivity	7.2e-004 W mm^-1 C^-1

TABLE 27
Concrete 2 > Color

Red	Green	Blue
180	173	167

TABLE 28
Concrete 2 > Compressive Ultimate Strength

Compressive Ultimate Strength MPa
30

TABLE 29
Concrete 2 > Compressive Yield Strength

Compressive Yield Strength MPa
0

TABLE 30
Concrete 2 > Tensile Yield Strength

Tensile Yield Strength MPa
0

TABLE 31
Concrete 2 > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
2.9

TABLE 32
Concrete 2 > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 33
Concrete 2 > Isotropic Elasticity

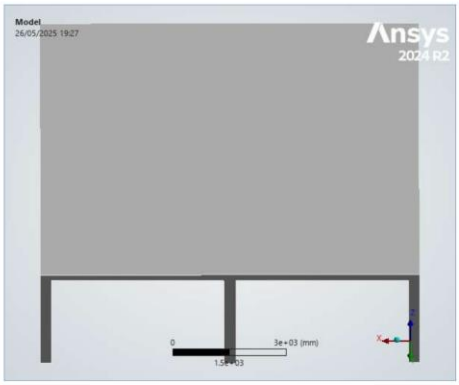
Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	Temperature C
32800	0.2	18222	13667	

200mm

Ansys

Project*

Author	Daniel Blanco Blanco
Prepared for	Bachelor Thesis
First Saved	Tuesday, May 13, 2025
Last Saved	Monday, May 26, 2025
Product Version	2024 R2
Save Project Before Solution	No
Save Project After Solution	No



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- Units
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  - Geometry Imports
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  - Geometry
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  - Construction Geometry
    - Path
  - Materials
  - Coordinate Systems
  - Mesh
    - Mesh Controls
  - Static Structural (A5)
    - Analysis Settings
    - Standard Earth Gravity
    - Loads
    - Solution (A6)
      - Solution Information
      - Results
      - Probes
- Material Data
  - Concrete 2

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

TABLE 2
Model (A4) > Geometry Imports

Object Name	*Geometry Imports*
State	Solved

TABLE 3
Model (A4) > Geometry Imports > Geometry Import (A3)

Object Name	*Geometry Import (A3)*
State	Solved
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	

Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Geometry

TABLE 4
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	62526
Elements	16830
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes

Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*SYS\Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	Concrete 2
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Centroid X	5000. mm
Centroid Y	5000. mm
Centroid Z	-62.913 mm
Moment of Inertia Ip1	5.2571e+011 kg·mm²
Moment of Inertia Ip2	5.2571e+011 kg·mm²
Moment of Inertia Ip3	1.0176e+012 kg·mm²
Statistics	

Nodes	62526
Elements	16830
Mesh Metric	None
CAD Attributes	
PartTolerance:	0,00000001
SCRootPartComponent	
Color:128,128,255	

TABLE 6
Model (A4) > Construction Geometry

Object Name	*Construction Geometry*
State	Fully Defined
Display	
Show Mesh	No

TABLE 7
Model (A4) > Construction Geometry > Paths

Object Name	*Path*
State	Fully Defined
Definition	
Path Type	Two Points
Path Coordinate System	Global Coordinate System
Number of Sampling Points	47.
Suppressed	No
Start	
Coordinate System	Global Coordinate System
Start X Coordinate	5000. mm
Start Y Coordinate	300. mm
Start Z Coordinate	0. mm
Location	Defined
End	
Coordinate System	Global Coordinate System
End X Coordinate	5000. mm
End Y Coordinate	300. mm
End Z Coordinate	200. mm
Location	Defined

TABLE 8
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	2
Material Assignments	0

Coordinate Systems

TABLE 9
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm

Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]
Transfer Properties	
Source	
Read Only	No

Mesh

TABLE 10
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Nonlinear Mechanical
Element Order	Program Controlled
Element Size	500.0 mm
Sizing	
Growth Rate	Default (1.5)
Max Size	Default (1000.0 mm)
Mesh Defeaturing	Yes
Defeature Size	Default (2.5 mm)
Capture Curvature	Yes
Curvature Min Size	Default (5.0 mm)
Curvature Normal Angle	Default (60.0°)
Capture Proximity	No
Bounding Box Diagonal	14478 mm
Average Surface Area	6.1364e+006 mm²
Minimum Edge Length	300.0 mm
Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.9)
Target Jacobian Ratio (Corner Nodes)	Default (4.e-002)
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
Inflation Element Type	Wedges
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (4.5 mm)
Generate Pinch on Refresh	No
Statistics	
Nodes	62526
Elements	16830
Show Detailed Statistics	No

TABLE 11
Model (A4) > Mesh > Mesh Controls

Object Name	*Hex Dominant Method*	*Face Sizing*	*Face Sizing 2*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body	2 Faces	37 Faces
Definition			
Suppressed	No		
Method	Hex Dominant		
Element Order	Use Global Setting		
Free Face Mesh Type	All Quad		
Control Messages	Yes, Click To Display...		
Type		Element Size	
Element Size		200.0 mm	100.0 mm
Advanced			
Defeature Size		Default (2.5 mm)	
Influence Volume		No	
Growth Rate		Default (1.5)	
Capture Curvature		Yes	
Curvature Normal Angle		Default (60.0°)	
Local Min Size		Default (5.0 mm)	
Capture Proximity		No	

Static Structural (A5)

TABLE 12
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 13
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart	Program Controlled

Points	
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Program Controlled
Output Controls	
Output Selection	None
Stress	Yes
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

TABLE 14
Model (A4) > Static Structural (A5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. mm/s² (ramped)
Y Component	0. mm/s² (ramped)
Z Component	-9806.6 mm/s² (ramped)
Suppressed	No
Direction	-Z Direction

FIGURE 1
Model (A4) > Static Structural (A5) > Standard Earth Gravity

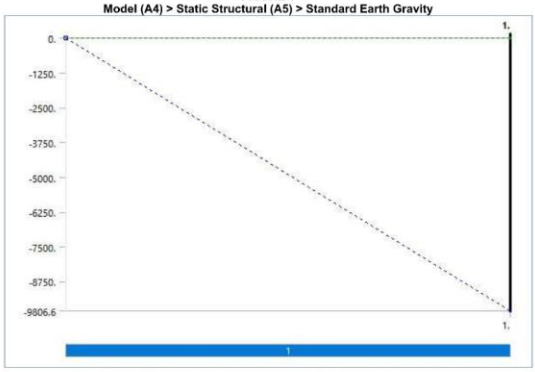


TABLE 15
Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Fixed Support 2*	*Fixed Support 3*	*Fixed Support 4*	*Fixed Support 5*	*Fixed Support 6*	*Fixed Support 7*	*Fixed Support 8*	*Fixed Support 9*	*Force*	*Pressure*
State	Fully Defined									Suppressed	Fully Defined
Scope											
Scoping Method	Geometry Selection										
Geometry	1 Face										
Definition											
Type	Fixed Support									Force	Pressure
Suppressed	No									Yes	No
Define By										Vector	Normal To
Applied By										Surface Effect	
Magnitude										1.e+006 N (ramped)	1.e-002 MPa (ramped)
Direction										Defined	
Loaded Area											Deformed

FIGURE 2
Model (A4) > Static Structural (A5) > Force

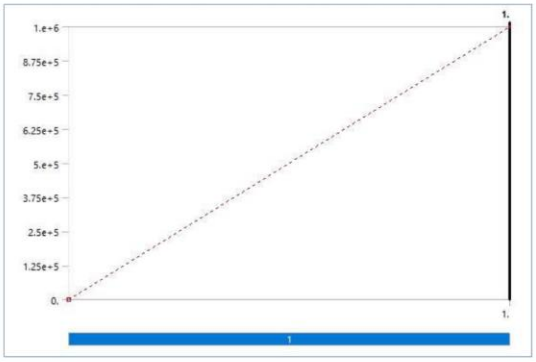
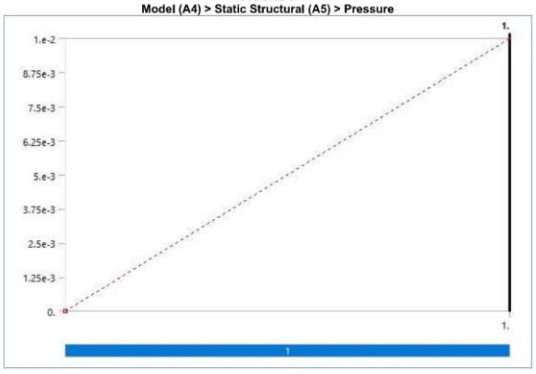


FIGURE 3
Model (A4) > Static Structural (A5) > Pressure



Solution (A6)

TABLE 16
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.

Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	6. s
MAPDL Memory Used	509. MB
MAPDL Result File Size	17.563 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 17
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 18
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*X Stress*	*Y Stress*	*Z Normal Stress*
State	Solved			
Scope				
Scoping Method	Geometry Selection	Path		
Geometry	All Bodies			
Path		Path		
Definition				
Type	Total Deformation	Linearized Normal Stress		
By	Time		Result Set	Time
Display Time	Last			Last
Separate Data by Entity	No			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation		X Axis	Y Axis	Z Axis
Subtype		Total		
Coordinate System		Global Coordinate System		
Zero Through-Thickness Bending Stress		No		
Set Number			Last	
Results				
Minimum	0. mm			
Maximum	3.6853 mm			
Average	1.2586 mm			
Minimum Occurs On	SYS\Solid			
Maximum Occurs On	SYS\Solid			
Total (Inside)		-8.0432 MPa	-9.6265 MPa	-11.048 MPa
Total (Center)		0.32523 MPa	0.37443 MPa	-1.5775 MPa
Total (Outside)		8.6772 MPa	6.341 MPa	-6.2345e-002 MPa

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

FIGURE 4
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

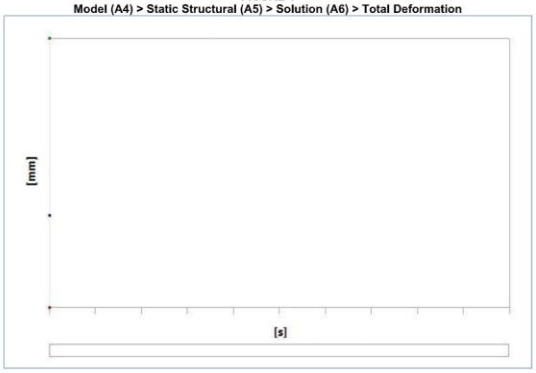


TABLE 19
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.	0.	3.6853	1.2586

FIGURE 5
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

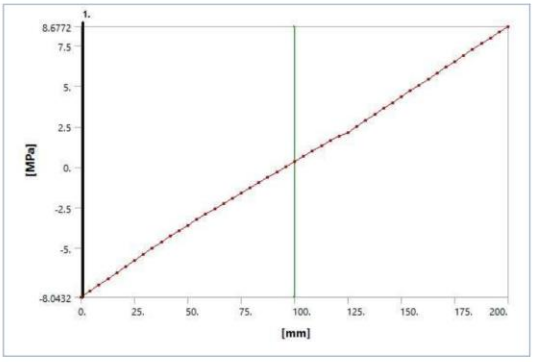


TABLE 20
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

Length [mm]	Total [MPa]
0.	-8.0432
4.1667	-7.6655
8.3333	-7.2877
12.5	-6.9102
16.667	-6.5348
20.833	-6.1578
25.	-5.7808
29.167	-5.4039
33.333	-5.0271
37.5	-4.6502
41.667	-4.2735
45.833	-3.9175
50.	-3.5849
54.167	-3.2522
58.333	-2.9196
62.5	-2.5869
66.667	-2.2542
70.833	-1.9243
75.	-1.5972
79.167	-1.2701
83.333	-0.94302
87.5	-0.61592
91.667	-0.29548
95.833	9.6599e-003
100.	0.32523
104.17	0.64692
108.33	0.97269
112.5	1.3015
116.67	1.6196
120.83	1.8903
125.	2.1482

129.17	2.5326
133.33	2.8954
137.5	3.257
141.67	3.6191
145.83	3.9817
150.	4.3448
154.17	4.7083
158.33	5.0724
162.5	5.437
166.67	5.8021
170.83	6.1678
175.	6.5339
179.17	6.9005
183.33	7.2677
187.5	7.6354
191.67	7.9931
195.83	8.3366
200.	8.6772

FIGURE 6
Model (A4) > Static Structural (A5) > Solution (A6) > Y Stress

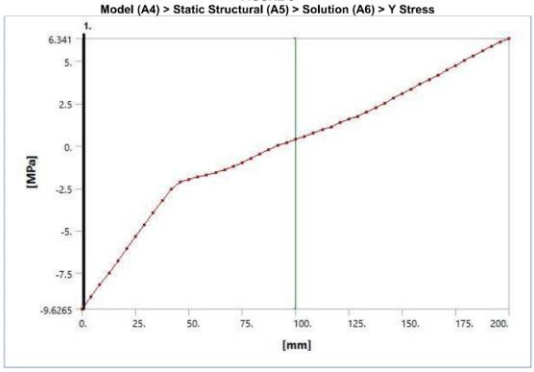


TABLE 21
Model (A4) > Static Structural (A5) > Solution (A6) > Y Stress

Length [mm]	Total [MPa]
0.	-9.6265
4.1667	-8.9147
8.3333	-8.2032
12.5	-7.4921
16.667	-6.7835
20.833	-6.0731
25.	-5.363
29.167	-4.653
33.333	-3.9432
37.5	-3.2336

41.667	-2.5243
45.833	-2.1118
50.	-1.9733
54.167	-1.8347
58.333	-1.6961
62.5	-1.5576
66.667	-1.419
70.833	-1.2257
75.	-0.97563
79.167	-0.72561
83.333	-0.47558
87.5	-0.22556
91.667	1.1054e-002
95.833	0.19166
100.	0.37443
104.17	0.56109
108.33	0.75036
112.5	0.94154
116.67	1.1462
120.83	1.3844
125.	1.6045
129.17	1.7253
133.33	1.9872
137.5	2.2595
141.67	2.5328
145.83	2.8072
150.	3.0828
154.17	3.3594
158.33	3.6372
162.5	3.916
166.67	4.196
170.83	4.4771
175.	4.7594
179.17	5.0427
183.33	5.3273
187.5	5.6129
191.67	5.8763
195.83	6.1101
200.	6.341

FIGURE 7
Model (A4) > Static Structural (A5) > Solution (A6) > Z Normal Stress

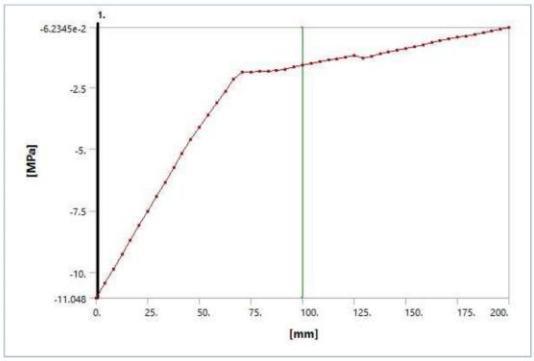


TABLE 22
Model (A4) > Static Structural (A5) > Solution (A6) > Z Normal Stress

Length [mm]	Total [MPa]
0.	-11.048
4.1667	-10.458
8.3333	-9.8679
12.5	-9.2785
16.667	-8.6936
20.833	-8.1058
25.	-7.5183
29.167	-6.9312
33.333	-6.3445
37.5	-5.7581
41.667	-5.1722
45.833	-4.6039
50.	-4.1134
54.167	-3.623
58.333	-3.1325
62.5	-2.642
66.667	-2.1515
70.833	-1.891
75.	-1.8683
79.167	-1.8456
83.333	-1.8229
87.5	-1.8002
91.667	-1.7556
95.833	-1.656
100.	-1.5775
104.17	-1.5091
108.33	-1.4476
112.5	-1.3912
116.67	-1.3376
120.83	-1.269
125.	-1.1844

129.17	-1.2904
133.33	-1.2204
137.5	-1.14
141.67	-1.0608
145.83	-0.98281
150.	-0.90603
154.17	-0.83049
158.33	-0.75613
162.5	-0.68297
166.67	-0.61104
170.83	-0.54033
175.	-0.47085
179.17	-0.40261
183.33	-0.33561
187.5	-0.26986
191.67	-0.20039
195.83	-0.12893
200.	-6.2345e-002

TABLE 23
Model (A4) > Static Structural (A5) > Solution (A6) > Probes

Object Name	*Force Reaction*	*Deformation Probe*
State	Solved	
Definition		
Type	Force Reaction	Deformation
Location Method	Boundary Condition	Geometry Selection
Boundary Condition	Fixed Support 5	
Orientation	Global Coordinate System	
Suppressed	No	
Geometry		Defined
X Coordinate		5000.1 mm
Y Coordinate		300.02 mm
Z Coordinate		200. mm
Options		
Result Selection	All	
Display Time	End Time	
Results		
X Axis	-50.723 N	-8.1261e-004 mm
Y Axis	43.154 N	0.17079 mm
Z Axis	4.796e+005 N	-0.4018 mm
Total	4.796e+005 N	0.4366 mm
Maximum Value Over Time		
X Axis	-50.723 N	-8.1261e-004 mm
Y Axis	43.154 N	0.17079 mm
Z Axis	4.796e+005 N	-0.4018 mm
Total	4.796e+005 N	0.4366 mm
Minimum Value Over Time		
X Axis	-50.723 N	-8.1261e-004 mm
Y Axis	43.154 N	0.17079 mm
Z Axis	4.796e+005 N	-0.4018 mm
Total	4.796e+005 N	0.4366 mm
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Force Reaction



TABLE 24
Model (A4) > Static Structural (A5) > Solution (A6) > Force Reaction

Time [s]	Force Reaction (X) [N]	Force Reaction (Y) [N]	Force Reaction (Z) [N]	Force Reaction (Total) [N]
1.	-50.723	43.154	4.796e+005	4.796e+005

FIGURE 9
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

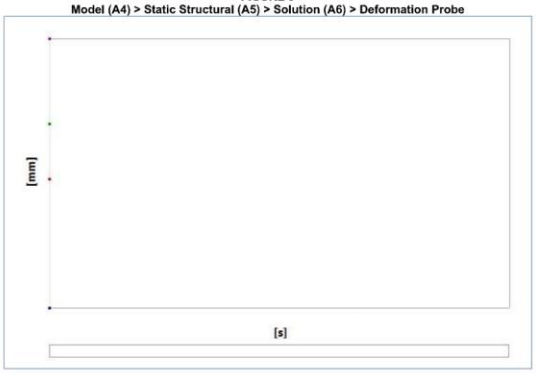


TABLE 25
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

Time	Deformation Probe (X)	Deformation Probe (Y)	Deformation Probe (Z)	Deformation Probe (Total)

[s]	[mm]	[mm]	[mm]	[mm]
1.	-8.1261e-004	0.17079	-0.4018	0.4366

Material Data

Concrete 2

TABLE 26
Concrete 2 > Constants

Density	2.5e-006 kg mm^-3
Coefficient of Thermal Expansion	1.4e-005 C^-1
Specific Heat	7.8e+005 mJ kg^-1 C^-1
Thermal Conductivity	7.2e-004 W mm^-1 C^-1

TABLE 27
Concrete 2 > Color

Red	Green	Blue
180	173	167

TABLE 28
Concrete 2 > Compressive Ultimate Strength

Compressive Ultimate Strength MPa
30

TABLE 29
Concrete 2 > Compressive Yield Strength

Compressive Yield Strength MPa
0

TABLE 30
Concrete 2 > Tensile Yield Strength

Tensile Yield Strength MPa
0

TABLE 31
Concrete 2 > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
2.9

TABLE 32
Concrete 2 > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 33
Concrete 2 > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	Temperature C
32800	0.2	18222	13667	

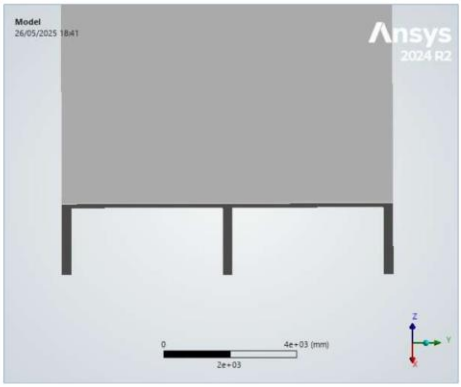
100mm



Ansys

Project*

Author	Daniel Blanco Blanco
Prepared for	Bachelor Thesis
First Saved	Tuesday, May 13, 2025
Last Saved	Monday, May 26, 2025
Product Version	2024 R2
Save Project Before Solution	No
Save Project After Solution	No



Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Geometry

TABLE 4
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	143535
Elements	32427
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes

129.17	2.5783
133.33	2.7727
137.5	2.9672

Contents

- Units
- Model (A4)
  - Geometry Imports
    - Geometry Import (A3)
  - Geometry
    - SYS\Solid
  - Construction Geometry
    - Path
  - Materials
  - Coordinate Systems
  - Mesh
    - Mesh Controls
  - Static Structural (A5)
    - Analysis Settings
    - Standard Earth Gravity
    - Loads
    - Solution (A6)
      - Solution Information
      - Results
      - Probes
- Material Data
  - Concrete 2

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

TABLE 2
Model (A4) > Geometry Imports

Object Name	*Geometry Imports*
State	Solved

TABLE 3
Model (A4) > Geometry Imports > Geometry Import (A3)

Object Name	*Geometry Import (A3)*
State	Solved
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	

Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*SYS\Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	Concrete 2
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Centroid X	5000. mm
Centroid Y	5000. mm
Centroid Z	-62.913 mm
Moment of Inertia Ip1	5.2571e+011 kg·mm²
Moment of Inertia Ip2	5.2571e+011 kg·mm²
Moment of Inertia Ip3	1.0176e+012 kg·mm²
Statistics	

Nodes	143535
Elements	32427
Mesh Metric	None
CAD Attributes	
PartTolerance:	0.00000001
SCRootPartComponent	
Color:128.128.255	

TABLE 6
Model (A4) > Construction Geometry

Object Name	*Construction Geometry*
State	Fully Defined
Display	
Show Mesh	No

TABLE 7
Model (A4) > Construction Geometry > Paths

Object Name	*Path*
State	Fully Defined
Definition	
Path Type	Two Points
Path Coordinate System	Global Coordinate System
Number of Sampling Points	47.
Suppressed	No
Start	
Coordinate System	Global Coordinate System
Start X Coordinate	5000. mm
Start Y Coordinate	300. mm
Start Z Coordinate	0. mm
Location	Defined
End	
Coordinate System	Global Coordinate System
End X Coordinate	5000. mm
End Y Coordinate	300. mm
End Z Coordinate	200. mm
Location	Defined

TABLE 8
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	2
Material Assignments	0

Coordinate Systems

TABLE 9
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm

Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]
Transfer Properties	
Source	
Read Only	No

Mesh

TABLE 10
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Nonlinear Mechanical
Element Order	Program Controlled
Element Size	500.0 mm
Sizing	
Growth Rate	Default (1.5)
Max Size	Default (1000.0 mm)
Mesh Defeaturing	Yes
Defeature Size	Default (2.5 mm)
Capture Curvature	Yes
Curvature Min Size	Default (5.0 mm)
Curvature Normal Angle	Default (60.0°)
Capture Proximity	No
Bounding Box Diagonal	14478 mm
Average Surface Area	6.1364e+006 mm²
Minimum Edge Length	300.0 mm
Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.9)
Target Jacobian Ratio (Corner Nodes)	Default (4.e-002)
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
Inflation Element Type	Wedges
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (4.5 mm)
Generate Pinch on Refresh	No
Statistics	
Nodes	143535
Elements	32427
Show Detailed Statistics	No

TABLE 11
Model (A4) > Mesh > Mesh Controls

Object Name	*Hex Dominant Method*	*Face Sizing*	*Face Sizing 2*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body	2 Faces	37 Faces
Definition			
Suppressed	No		
Method	Hex Dominant		
Element Order	Use Global Setting		
Free Face Mesh Type	All Quad		
Control Messages	Yes, Click To Display...		
Type		Element Size	
Element Size		100.0 mm	
Advanced			
Defeature Size		Default (2.5 mm)	
Influence Volume		No	
Growth Rate		Default (1.5)	
Capture Curvature		Yes	
Curvature Normal Angle		Default (60.0°)	
Local Min Size		Default (5.0 mm)	
Capture Proximity		No	

Static Structural (A5)

TABLE 12
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 13
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart	Program Controlled

Points	
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Program Controlled
Output Controls	
Output Selection	None
Stress	Yes
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\Danie\Dropbox\Daniel\Universiteit Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

TABLE 14
Model (A4) > Static Structural (A5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. mm/s² (ramped)
Y Component	0. mm/s² (ramped)
Z Component	-9806.6 mm/s² (ramped)
Suppressed	No
Direction	-Z Direction

TABLE 15
Model (A4) > Static Structural (A5) > Loads

Object Name	Fixed Support	Fixed Support 2	Fixed Support 3	Fixed Support 4	Fixed Support 5	Fixed Support 6	Fixed Support 7	Fixed Support 8	Fixed Support 9	Force	Pressure
State	Fully Defined									Suppressed	Fully Defined
Scope											
Scoping Method	Geometry Selection										
Geometry	1 Face										
Definition											
Type	Fixed Support									Force	Pressure
Suppressed	No									Yes	No
Define By										Vector	Normal To
Applied By										Surface Effect	
Magnitude										1.e+006 N (ramped)	1.e-002 MPa (ramped)
Direction										Defined	
Loaded Area											Deformed

Solution (A6)

TABLE 16
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.
Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	8. s
MAPDL Memory Used	972. MB
MAPDL Result File Size	37.125 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 17
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 18
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*X Stress*	*Y Stress*	*Z Normal Stress*
State	Solved			
Scope				
Scoping Method	Geometry Selection	Path		
Geometry	All Bodies			
Path		Path		
Definition				
Type	Total Deformation	Linearized Normal Stress		
By	Time		Result Set	Time
Display Time	Last			Last
Separate Data by Entity	No			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation		X Axis	Y Axis	Z Axis
Subtype		Total		
Coordinate System		Global Coordinate System		
Zero Through-Thickness Bending Stress		No		
Set Number			Last	
Results				
Minimum	0. mm			
Maximum	3.6643 mm			
Average	2.243 mm			
Minimum Occurs On	SYS\Solid			
Maximum Occurs On	SYS\Solid			
Total (Inside)		-7.3216 MPa	-6.9731 MPa	-8.2162 MPa
Total (Center)		0.33262 MPa	1.1139 MPa	-1.8836 MPa
Total (Outside)		8.4585 MPa	5.8831 MPa	0.20291 MPa
Information				
Time	1. s			
Load Step	1			
Substep	1			
Iteration Number	1			

FIGURE 1
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation



TABLE 19
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.	0.	3.6643	2.243

FIGURE 2
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

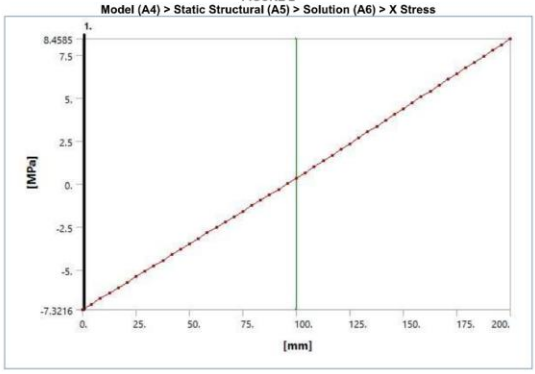


TABLE 20
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

Length [mm]	Total [MPa]

0.	-7.3216
4.1667	-7.0017
8.3333	-6.6819
12.5	-6.3622
16.667	-6.0426
20.833	-5.7231
25.	-5.4037
29.167	-5.0844
33.333	-4.7652
37.5	-4.4461
41.667	-4.127
45.833	-3.8081
50.	-3.4892
54.167	-3.1703
58.333	-2.8516
62.5	-2.5329
66.667	-2.2143
70.833	-1.8957
75.	-1.5772
79.167	-1.2588
83.333	-0.94037
87.5	-0.62204
91.667	-0.30377
95.833	1.4451e-002
100.	0.33262
104.17	0.65653
108.33	0.99597
112.5	1.3354
116.67	1.6748
120.83	2.0142
125.	2.3535
129.17	2.6929
133.33	3.0322
137.5	3.3715
141.67	3.7108
145.83	4.05
150.	4.3893
154.17	4.7285
158.33	5.0677
162.5	5.4069
166.67	5.746
170.83	6.0852
175.	6.4243
179.17	6.7634
183.33	7.1024
187.5	7.4415
191.67	7.7805
195.83	8.1195
200.	8.4585

FIGURE 3
Model (A4) > Static Structural (A5) > Solution (A6) > Y Stress



TABLE 25
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

Time [s]	Deformation Probe (X) [mm]	Deformation Probe (Y) [mm]	Deformation Probe (Z) [mm]	Deformation Probe (Total) [mm]
1.	4.4728e-003	0.17039	-0.40012	0.43491

Material Data

Concrete 2

TABLE 26
Concrete 2 > Constants

Density	2.5e-006 kg mm^-3
Coefficient of Thermal Expansion	1.4e-005 C^-1
Specific Heat	7.8e+005 mJ kg^-1 C^-1
Thermal Conductivity	7.2e-004 W mm^-1 C^-1

TABLE 27
Concrete 2 > Color

Red	Green	Blue
180	173	167

TABLE 28
Concrete 2 > Compressive Ultimate Strength

Compressive Ultimate Strength MPa
30

TABLE 29
Concrete 2 > Compressive Yield Strength

Compressive Yield Strength MPa
0

TABLE 30
Concrete 2 > Tensile Yield Strength

Tensile Yield Strength MPa
0

TABLE 31
Concrete 2 > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
2.9

TABLE 32
Concrete 2 > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 33
Concrete 2 > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	Temperature C
32800	0.2	18222	13667	

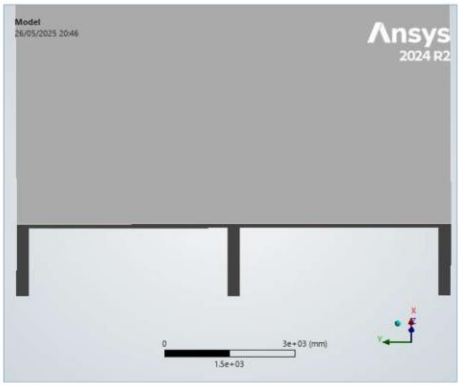
file:///C:/Users/Danie/AppData/Roaming/Ansys/v242/Mechanical_Report/Mechanical_R... 26/05/2025

50mm

Ansys

Project*

Author	Daniel Blanco Blanco
Prepared for	Bachelor Thesis
First Saved	Tuesday, May 13, 2025
Last Saved	Monday, May 26, 2025
Product Version	2024 R2
Save Project Before Solution	No
Save Project After Solution	No



Contents

- Units
- Model (A4)
  - Geometry Imports
    - Geometry Import (A3)
  - Geometry
    - SYS\Solid
  - Construction Geometry
    - Path
  - Materials
  - Coordinate Systems
  - Mesh
    - Mesh Controls
  - Static Structural (A5)
    - Analysis Settings
    - Standard Earth Gravity
    - Loads
    - Solution (A6)
      - Solution Information
      - Results
      - Probes
- Material Data
  - Concrete 2

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

TABLE 2
Model (A4) > Geometry Imports

Object Name	*Geometry Imports*
State	Solved

TABLE 3
Model (A4) > Geometry Imports > Geometry Import (A3)

Object Name	*Geometry Import (A3)*
State	Solved
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	

Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Geometry

TABLE 4
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	961045
Elements	241558
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes

Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*SYS\Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	Concrete 2
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Centroid X	5000. mm
Centroid Y	5000. mm
Centroid Z	-62.913 mm
Moment of Inertia Ip1	5.2571e+011 kg·mm²
Moment of Inertia Ip2	5.2571e+011 kg·mm²
Moment of Inertia Ip3	1.0176e+012 kg·mm²
Statistics	

Nodes	961045
Elements	241558
Mesh Metric	None
CAD Attributes	
PartTolerance:	0.00000001
SCRootPartComponent	
Color:128,128,255	

TABLE 6
Model (A4) > Construction Geometry

Object Name	*Construction Geometry*
State	Fully Defined
Display	
Show Mesh	No

TABLE 7
Model (A4) > Construction Geometry > Paths

Object Name	*Path*
State	Fully Defined
Definition	
Path Type	Two Points
Path Coordinate System	Global Coordinate System
Number of Sampling Points	47.
Suppressed	No
Start	
Coordinate System	Global Coordinate System
Start X Coordinate	5000. mm
Start Y Coordinate	300. mm
Start Z Coordinate	0. mm
Location	Defined
End	
Coordinate System	Global Coordinate System
End X Coordinate	5000. mm
End Y Coordinate	300. mm
End Z Coordinate	200. mm
Location	Defined

TABLE 8
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	2
Material Assignments	0

Coordinate Systems

TABLE 9
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm

Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]
Transfer Properties	
Source	
Read Only	No

Mesh

TABLE 10
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Nonlinear Mechanical
Element Order	Program Controlled
Element Size	500.0 mm
Sizing	
Growth Rate	Default (1.5)
Max Size	Default (1000.0 mm)
Mesh Defeaturing	Yes
Defeature Size	Default (2.5 mm)
Capture Curvature	Yes
Curvature Min Size	Default (5.0 mm)
Curvature Normal Angle	Default (60.0°)
Capture Proximity	No
Bounding Box Diagonal	14478 mm
Average Surface Area	6.1364e+006 mm²
Minimum Edge Length	300.0 mm
Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.9)
Target Jacobian Ratio (Corner Nodes)	Default (4.e-002)
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
Inflation Element Type	Wedges
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (4.5 mm)
Generate Pinch on Refresh	No
Statistics	
Nodes	961045
Elements	241558
Show Detailed Statistics	No

TABLE 11
Model (A4) > Mesh > Mesh Controls

Object Name	*Hex Dominant Method*	*Face Sizing*	*Face Sizing 2*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body	2 Faces	37 Faces
Definition			
Suppressed	No		
Method	Hex Dominant		
Element Order	Use Global Setting		
Free Face Mesh Type	All Quad		
Control Messages	Yes, Click To Display...		
Type		Element Size	
Element Size		50.0 mm	100.0 mm
Advanced			
Defeature Size		Default (2.5 mm)	
Influence Volume		No	
Growth Rate		Default (1.5)	
Capture Curvature		Yes	
Curvature Normal Angle		Default (60.0°)	
Local Min Size		Default (5.0 mm)	
Capture Proximity		No	

Static Structural (A5)

TABLE 12
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 13
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart	Program Controlled

Points	
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Program Controlled
Output Controls	
Output Selection	None
Stress	Yes
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

TABLE 14
Model (A4) > Static Structural (A5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. mm/s² (ramped)
Y Component	0. mm/s² (ramped)
Z Component	-9806.6 mm/s² (ramped)
Suppressed	No
Direction	-Z Direction

FIGURE 1
Model (A4) > Static Structural (A5) > Standard Earth Gravity

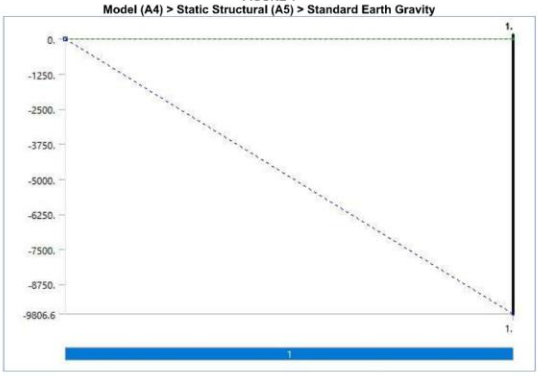


TABLE 15
Model (A4) > Static Structural (A5) > Loads

Object Name	*Fixed Support*	*Fixed Support 2*	*Fixed Support 3*	*Fixed Support 4*	*Fixed Support 5*	*Fixed Support 6*	*Fixed Support 7*	*Fixed Support 8*	*Fixed Support 9*	*Force*	*Pressure*
State	Fully Defined									Suppressed	Fully Defined
Scope											
Scoping Method	Geometry Selection										
Geometry	1 Face										
Definition											
Type	Fixed Support									Force	Pressure
Suppressed	No									Yes	No
Define By										Vector	Normal To
Applied By										Surface Effect	
Magnitude										1.e+006 N (ramped)	1.e-002 MPa (ramped)
Direction										Defined	
Loaded Area											Deformed

FIGURE 2
Model (A4) > Static Structural (A5) > Force

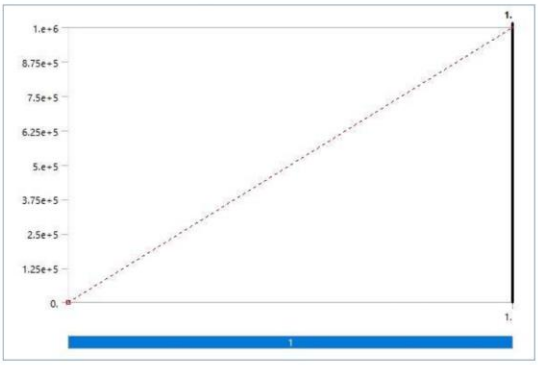
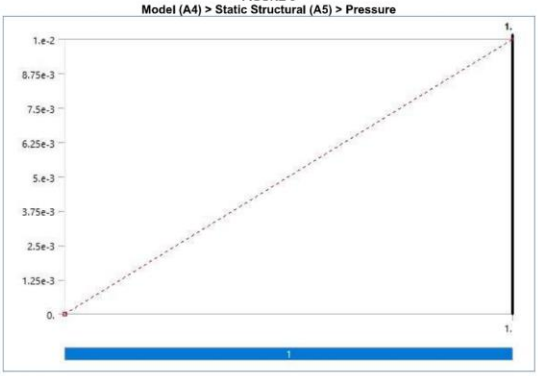


FIGURE 3
Model (A4) > Static Structural (A5) > Pressure



Solution (A6)

TABLE 16
Model (A4) > Static Structural (A5) > Solution

Object Name	*Solution (A6)*
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.

Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	1 m 15 s
MAPDL Memory Used	5.6973 GB
MAPDL Result File Size	259.19 MB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 17
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	*Solution Information*
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 18
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	*Total Deformation*	*X Stress*	*Y Stress*	*Z Normal Stress*
State	Solved			
Scope				
Scoping Method	Geometry Selection	Path		
Geometry	All Bodies			
Path		Path		
Definition				
Type	Total Deformation	Linearized Normal Stress		
By	Time		Result Set	Time
Display Time	Last			Last
Separate Data by Entity	No			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation		X Axis	Y Axis	Z Axis
Subtype		Total		
Coordinate System		Global Coordinate System		
Zero Through-Thickness Bending Stress		No		
Set Number			Last	
Results				
Minimum	0. mm			
Maximum	3.675 mm			
Average	2.4248 mm			
Minimum Occurs On	SYS\Solid			
Maximum Occurs On	SYS\Solid			
Total (Inside)		-7.9489 MPa	-10.063 MPa	-10.494 MPa
Total (Center)		0.25926 MPa	0.43005 MPa	-1.7409 MPa
Total (Outside)		8.5236 MPa	6.3665 MPa	7.6216e-002 MPa

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

FIGURE 4
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

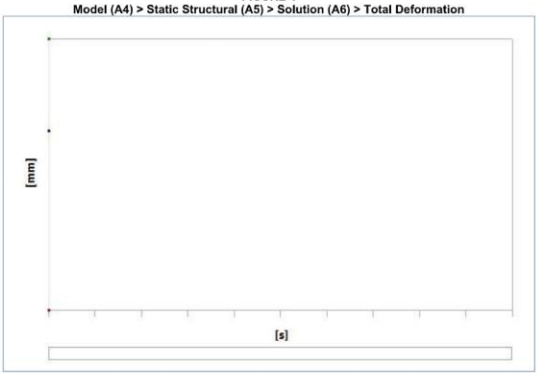


TABLE 19
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.	0.	3.675	2.4248

FIGURE 5
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

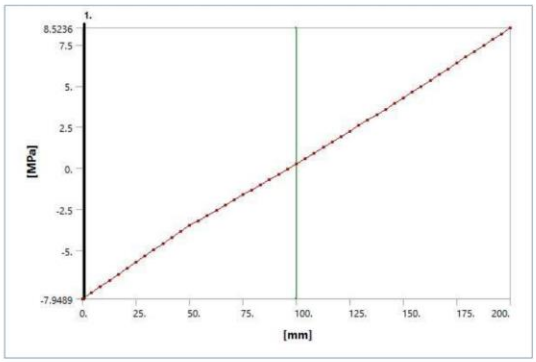


TABLE 20
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

Length [mm]	Total [MPa]
0.	-7.9489
4.1667	-7.5893
8.3333	-7.2007
12.5	-6.826
16.667	-6.4512
20.833	-6.0763
25.	-5.7017
29.167	-5.3277
33.333	-4.9546
37.5	-4.5827
41.667	-4.2125
45.833	-3.8446
50.	-3.4916
54.167	-3.181
58.333	-2.8706
62.5	-2.5604
66.667	-2.2502
70.833	-1.9401
75.	-1.63
79.167	-1.3199
83.333	-1.0098
87.5	-0.6996
91.667	-0.38927
95.833	-7.3705e-002
100.	0.25926
104.17	0.59205
108.33	0.92469
112.5	1.2572
116.67	1.5896
120.83	1.922
125.	2.2544

129.17	2.5867
133.33	2.9191
137.5	3.2515
141.67	3.5841
145.83	3.9168
150.	4.2582
154.17	4.6134
158.33	4.9686
162.5	5.3239
166.67	5.6792
170.83	6.0346
175.	6.39
179.17	6.7454
183.33	7.101
187.5	7.4565
191.67	7.8122
195.83	8.1678
200.	8.5236

FIGURE 6
Model (A4) > Static Structural (A5) > Solution (A6) > Y Stress

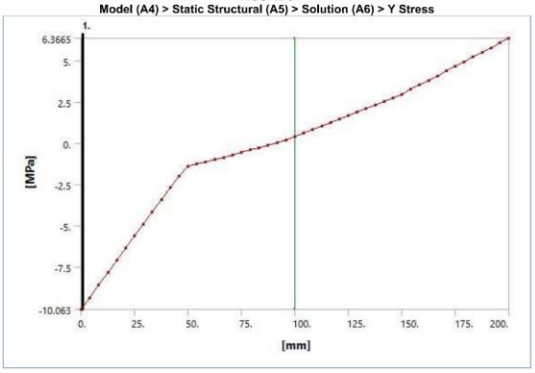


TABLE 21
Model (A4) > Static Structural (A5) > Solution (A6) > Y Stress

Length [mm]	Total [MPa]
0.	-10.063
4.1667	-9.3577
8.3333	-8.5827
12.5	-7.8417
16.667	-7.1006
20.833	-6.3601
25.	-5.6207
29.167	-4.8833
33.333	-4.1487
37.5	-3.418

41.667	-2.6923
45.833	-1.9732
50.	-1.3913
54.167	-1.2576
58.333	-1.1215
62.5	-0.983
66.667	-0.84207
70.833	-0.69873
75.	-0.55302
79.167	-0.40496
83.333	-0.25459
87.5	-0.10196
91.667	5.2877e-002
95.833	0.22135
100.	0.43005
104.17	0.63883
108.33	0.8477
112.5	1.0567
116.67	1.2659
120.83	1.4752
125.	1.6848
129.17	1.8947
133.33	2.1049
137.5	2.3155
141.67	2.5265
145.83	2.7379
150.	2.9768
154.17	3.259
158.33	3.5413
162.5	3.8236
166.67	4.1059
170.83	4.3883
175.	4.6707
179.17	4.9532
183.33	5.2358
187.5	5.5184
191.67	5.801
195.83	6.0837
200.	6.3665

FIGURE 7
Model (A4) > Static Structural (A5) > Solution (A6) > Z Normal Stress

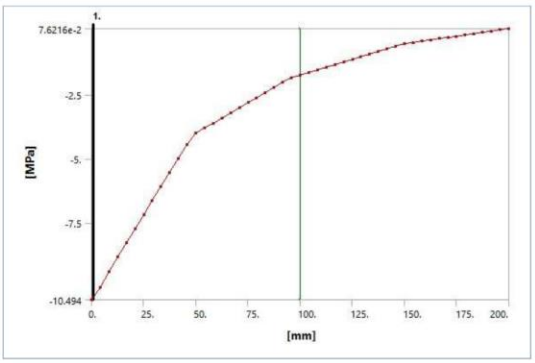


TABLE 22
Model (A4) > Static Structural (A5) > Solution (A6) > Z Normal Stress

Length [mm]	Total [MPa]
0.	-10.494
4.1667	-10.019
8.3333	-9.3853
12.5	-8.8297
16.667	-8.2741
20.833	-7.719
25.	-7.1652
29.167	-6.6135
33.333	-6.065
37.5	-5.5208
41.667	-4.9823
45.833	-4.4511
50.	-4.0006
54.167	-3.8011
58.333	-3.6022
62.5	-3.4037
66.667	-3.2057
70.833	-3.0079
75.	-2.8105
79.167	-2.6132
83.333	-2.4161
87.5	-2.219
91.667	-2.0219
95.833	-1.8456
100.	-1.7409
104.17	-1.6363
108.33	-1.5318
112.5	-1.4274
116.67	-1.323
120.83	-1.2187
125.	-1.1143

129.17	-1.01
133.33	-0.9056
137.5	-0.80114
141.67	-0.69659
145.83	-0.59191
150.	-0.5087
154.17	-0.45992
158.33	-0.41114
162.5	-0.36237
166.67	-0.31361
170.83	-0.26485
175.	-0.21611
179.17	-0.16737
183.33	-0.11864
187.5	-6.9915e-002
191.67	-2.1198e-002
195.83	2.7512e-002
200.	7.6216e-002

TABLE 23
Model (A4) > Static Structural (A5) > Solution (A6) > Probes

Object Name	*Force Reaction*	*Deformation Probe*
State	Solved	
Definition		
Type	Force Reaction	Deformation
Location Method	Boundary Condition	Geometry Selection
Boundary Condition	Fixed Support 5	
Orientation	Global Coordinate System	
Suppressed	No	
Geometry		Defined
X Coordinate		5000.1 mm
Y Coordinate		300.02 mm
Z Coordinate		200. mm
Options		
Result Selection	All	
Display Time	End Time	
Results		
X Axis	-3.5496 N	2.5334e-004 mm
Y Axis	-11.578 N	0.17258 mm
Z Axis	4.797e+005 N	-0.40104 mm
Total	4.797e+005 N	0.43659 mm
Maximum Value Over Time		
X Axis	-3.5496 N	2.5334e-004 mm
Y Axis	-11.578 N	0.17258 mm
Z Axis	4.797e+005 N	-0.40104 mm
Total	4.797e+005 N	0.43659 mm
Minimum Value Over Time		
X Axis	-3.5496 N	2.5334e-004 mm
Y Axis	-11.578 N	0.17258 mm
Z Axis	4.797e+005 N	-0.40104 mm
Total	4.797e+005 N	0.43659 mm
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Force Reaction



TABLE 24
Model (A4) > Static Structural (A5) > Solution (A6) > Force Reaction

Time [s]	Force Reaction (X) [N]	Force Reaction (Y) [N]	Force Reaction (Z) [N]	Force Reaction (Total) [N]
1.	-3.5496	-11.578	4.797e+005	4.797e+005

FIGURE 9
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

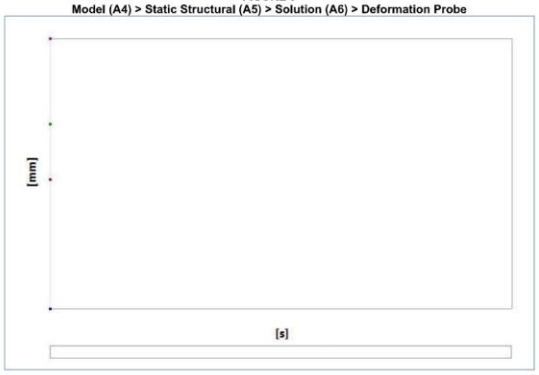


TABLE 25
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

Time	Deformation Probe (X)	Deformation Probe (Y)	Deformation Probe (Z)	Deformation Probe (Total)

[s]	[mm]	[mm]	[mm]	[mm]
1.	2.5334e-004	0.17258	-0.40104	0.43659

Material Data

Concrete 2

TABLE 26
Concrete 2 > Constants

Density	2.5e-006 kg mm^-3
Coefficient of Thermal Expansion	1.4e-005 C^-1
Specific Heat	7.8e+005 mJ kg^-1 C^-1
Thermal Conductivity	7.2e-004 W mm^-1 C^-1

TABLE 27
Concrete 2 > Color

Red	Green	Blue
180	173	167

TABLE 28
Concrete 2 > Compressive Ultimate Strength

Compressive Ultimate Strength MPa
30

TABLE 29
Concrete 2 > Compressive Yield Strength

Compressive Yield Strength MPa
0

TABLE 30
Concrete 2 > Tensile Yield Strength

Tensile Yield Strength MPa
0

TABLE 31
Concrete 2 > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
2.9

TABLE 32
Concrete 2 > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 33
Concrete 2 > Isotropic Elasticity

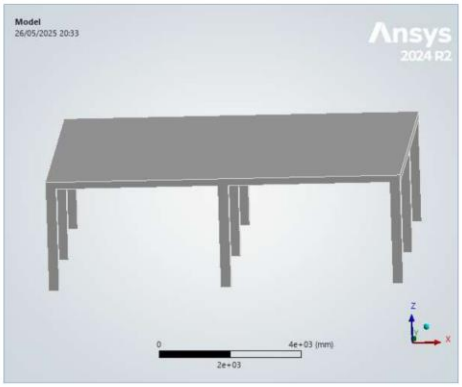
Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	Temperature C
32800	0.2	18222	13667	

25 mm

Ansys

Project*

Author	Daniel Blanco Blanco
Prepared for	Bachelor Thesis
First Saved	Tuesday, May 13, 2025
Last Saved	Monday, May 26, 2025
Product Version	2024 R2
Save Project Before Solution	No
Save Project After Solution	No



Contents

- Units
- Model (A4)
  - Geometry Imports
    - Geometry Import (A3)
  - Geometry
    - SYS\Solid
  - Construction Geometry
    - Path
  - Materials
  - Coordinate Systems
  - Mesh
    - Mesh Controls
  - Static Structural (A5)
    - Analysis Settings
    - Standard Earth Gravity
    - Loads
    - Solution (A6)
      - Solution Information
      - Results
      - Probes
- Material Data
  - Concrete 2

Units

TABLE 1

Unit System	Metric (mm, kg, N, s, mV, mA) Degrees rad/s Celsius
Angle	Degrees
Rotational Velocity	rad/s
Temperature	Celsius

Model (A4)

TABLE 2
Model (A4) > Geometry Imports

Object Name	*Geometry Imports*
State	Solved

TABLE 3
Model (A4) > Geometry Imports > Geometry Import (A3)

Object Name	*Geometry Import (A3)*
State	Solved
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes
Parameters	Independent
Parameter Key	

Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

Geometry

TABLE 4
Model (A4) > Geometry

Object Name	*Geometry*
State	Fully Defined
Definition	
Source	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\DM\SYS.dsco
Type	Discovery
Length Unit	Meters
Element Control	Program Controlled
Display Style	Body Color
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Scale Factor Value	1.
Statistics	
Bodies	1
Active Bodies	1
Nodes	5755347
Elements	1465054
Mesh Metric	None
Update Options	
Assign Default Material	No
Basic Geometry Options	
Solid Bodies	Yes
Surface Bodies	Yes
Line Bodies	Yes

Parameters	Independent
Parameter Key	
Attributes	Yes
Attribute Key	
Named Selections	Yes
Named Selection Key	
Material Properties	No
Advanced Geometry Options	
Use Associativity	Yes
Coordinate Systems	Yes
Coordinate System Key	
Reader Mode Saves Updated File	No
Use Instances	Yes
Smart CAD Update	Yes
Compare Parts On Update	No
Analysis Type	3-D
Mixed Import Resolution	None
Import Facet Quality	Source
Clean Bodies On Import	No
Stitch Surfaces On Import	None
Decompose Disjoint Geometry	Yes
Enclosure and Symmetry Processing	Yes

TABLE 5
Model (A4) > Geometry > Parts

Object Name	*SYS\Solid*
State	Meshed
Graphics Properties	
Visible	Yes
Transparency	1
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Treatment	None
Material	
Assignment	Concrete 2
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Length X	10000 mm
Length Y	10000 mm
Length Z	3100. mm
Properties	
Volume	2.2349e+010 mm³
Mass	55873 kg
Centroid X	5000. mm
Centroid Y	5000. mm
Centroid Z	-62.913 mm
Moment of Inertia Ip1	5.2571e+011 kg·mm²
Moment of Inertia Ip2	5.2571e+011 kg·mm²
Moment of Inertia Ip3	1.0176e+012 kg·mm²
Statistics	

Nodes	5755347
Elements	1465054
Mesh Metric	None
CAD Attributes	
PartTolerance:	0.00000001
SCRootPartComponent	
Color:128,128,255	

TABLE 6
Model (A4) > Construction Geometry

Object Name	*Construction Geometry*
State	Fully Defined
Display	
Show Mesh	No

TABLE 7
Model (A4) > Construction Geometry > Paths

Object Name	*Path*
State	Fully Defined
Definition	
Path Type	Two Points
Path Coordinate System	Global Coordinate System
Number of Sampling Points	47.
Suppressed	No
Start	
Coordinate System	Global Coordinate System
Start X Coordinate	5000. mm
Start Y Coordinate	300. mm
Start Z Coordinate	0. mm
Location	Defined
End	
Coordinate System	Global Coordinate System
End X Coordinate	5000. mm
End Y Coordinate	300. mm
End Z Coordinate	200. mm
Location	Defined

TABLE 8
Model (A4) > Materials

Object Name	*Materials*
State	Fully Defined
Statistics	
Materials	2
Material Assignments	0

Coordinate Systems

TABLE 9
Model (A4) > Coordinate Systems > Coordinate System

Object Name	*Global Coordinate System*
State	Fully Defined
Definition	
Type	Cartesian
Coordinate System ID	0.
Origin	
Origin X	0. mm
Origin Y	0. mm
Origin Z	0. mm

Directional Vectors	
X Axis Data	[1. 0. 0.]
Y Axis Data	[0. 1. 0.]
Z Axis Data	[0. 0. 1.]
Transfer Properties	
Source	
Read Only	No

Mesh

TABLE 10
Model (A4) > Mesh

Object Name	*Mesh*
State	Solved
Display	
Display Style	Use Geometry Setting
Defaults	
Physics Preference	Nonlinear Mechanical
Element Order	Program Controlled
Element Size	500.0 mm
Sizing	
Growth Rate	Default (1.5)
Max Size	Default (1000.0 mm)
Mesh Defeaturing	Yes
Defeature Size	Default (2.5 mm)
Capture Curvature	Yes
Curvature Min Size	Default (5.0 mm)
Curvature Normal Angle	Default (60.0°)
Capture Proximity	No
Bounding Box Diagonal	14478 mm
Average Surface Area	6.1364e+006 mm²
Minimum Edge Length	300.0 mm
Quality	
Check Mesh Quality	Yes, Errors
Target Skewness	Default (0.9)
Target Jacobian Ratio (Corner Nodes)	Default (4.e-002)
Mesh Metric	None
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	5
Growth Rate	1.2
Inflation Algorithm	Pre
Inflation Element Type	Wedges
View Advanced Options	No
Advanced	
Number of CPUs for Parallel Part Meshing	Program Controlled
Straight Sided Elements	No
Rigid Body Behavior	Dimensionally Reduced
Triangle Surface Mesher	Program Controlled
Topology Checking	Yes
Pinch Tolerance	Default (4.5 mm)
Generate Pinch on Refresh	No
Statistics	
Nodes	5755347
Elements	1465054
Show Detailed Statistics	No

TABLE 11
Model (A4) > Mesh > Mesh Controls

Object Name	*Hex Dominant Method*	*Face Sizing*	*Face Sizing 2*
State	Fully Defined		
Scope			
Scoping Method	Geometry Selection		
Geometry	1 Body	2 Faces	37 Faces
Definition			
Suppressed	No		
Method	Hex Dominant		
Element Order	Use Global Setting		
Free Face Mesh Type	All Quad		
Control Messages	Yes, Click To Display...		
Type		Element Size	
Element Size		25.0 mm	100.0 mm
Advanced			
Defeature Size		Default (2.5 mm)	
Influence Volume		No	
Growth Rate		Default (1.5)	
Capture Curvature		Yes	
Curvature Normal Angle		Default (60.0°)	
Local Min Size		Default (5.0 mm)	
Capture Proximity		No	

Static Structural (A5)

TABLE 12
Model (A4) > Analysis

Object Name	*Static Structural (A5)*
State	Solved
Definition	
Physics Type	Structural
Analysis Type	Static Structural
Solver Target	Mechanical APDL
Options	
Environment Temperature	22. °C
Generate Input Only	No

TABLE 13
Model (A4) > Static Structural (A5) > Analysis Settings

Object Name	*Analysis Settings*
State	Fully Defined
Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Program Controlled
Solver Controls	
Solver Type	Program Controlled
Weak Springs	Off
Solver Pivot Checking	Program Controlled
Large Deflection	Off
Inertia Relief	Off
Quasi-Static Solution	Off
Rotordynamics Controls	
Coriolis Effect	Off
Restart Controls	
Generate Restart	Program Controlled

Points	
Retain Files After Full Solve	No
Combine Restart Files	Program Controlled
Nonlinear Controls	
Newton-Raphson Option	Program Controlled
Force Convergence	Program Controlled
Moment Convergence	Program Controlled
Displacement Convergence	Program Controlled
Rotation Convergence	Program Controlled
Line Search	Program Controlled
Stabilization	Program Controlled
Advanced	
Inverse Option	No
Contact Split (DMP)	Program Controlled
Output Controls	
Output Selection	None
Stress	Yes
Back Stress	No
Strain	Yes
Contact Data	Yes
Nonlinear Data	No
Nodal Forces	No
Volume and Energy	Yes
Euler Angles	Yes
General Miscellaneous	No
Contact Miscellaneous	No
Store Results At	All Time Points
Result File Compression	Program Controlled
Analysis Data Management	
Solver Files Directory	C:\Users\Danie\Dropbox\Daniel\Universiteit\Bachelor 3\Bachelor Thesis\Simulation10x10x0.2 with columnas 3_files\dp0\SYS\MECH\
Future Analysis	None
Scratch Solver Files Directory	
Save MAPDL db	No
Contact Summary	Program Controlled
Delete Unneeded Files	Yes
Nonlinear Solution	No
Solver Units	Active System
Solver Unit System	nmm

TABLE 14
Model (A4) > Static Structural (A5) > Accelerations

Object Name	*Standard Earth Gravity*
State	Fully Defined
Scope	
Geometry	All Bodies
Definition	
Coordinate System	Global Coordinate System
X Component	0. mm/s² (ramped)
Y Component	0. mm/s² (ramped)
Z Component	-9806.6 mm/s² (ramped)
Suppressed	No
Direction	-Z Direction

FIGURE 1
Model (A4) > Static Structural (A5) > Standard Earth Gravity

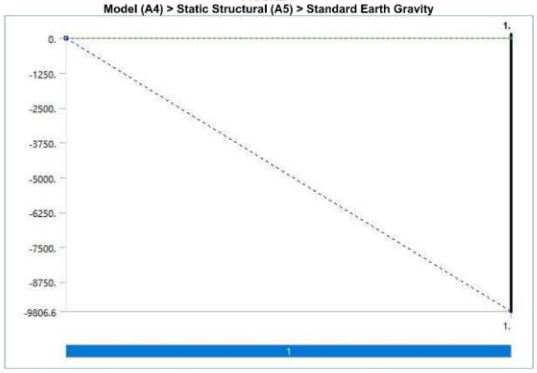


TABLE 15
Model (A4) > Static Structural (A5) > Loads

Object Name	Fixed Support	Fixed Support 2	Fixed Support 3	Fixed Support 4	Fixed Support 5	Fixed Support 6	Fixed Support 7	Fixed Support 8	Fixed Support 9	Force	Pressure
State	Fully Defined									Suppressed	Fully Defined
Scope											
Scoping Method	Geometry Selection										
Geometry	1 Face										
Definition											
Type	Fixed Support									Force	Pressure
Suppressed	No									Yes	No
Define By										Vector	Normal To
Applied By										Surface Effect	
Magnitude										1.e+006 N (ramped)	1.e-002 MPa (ramped)
Direction										Defined	
Loaded Area											Deformed

FIGURE 2
Model (A4) > Static Structural (A5) > Force

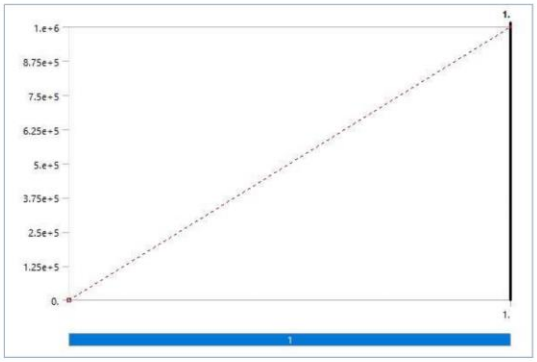
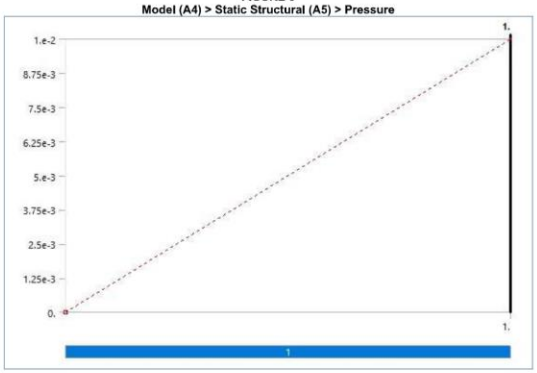


FIGURE 3
Model (A4) > Static Structural (A5) > Pressure



Solution (A6)

TABLE 16
Model (A4) > Static Structural (A5) > Solution

Object Name	Solution (A6)
State	Solved
Adaptive Mesh Refinement	
Max Refinement Loops	1.

Refinement Depth	2.
Information	
Status	Done
MAPDL Elapsed Time	9 m 12 s
MAPDL Memory Used	18.656 GB
MAPDL Result File Size	1.5161 GB
Post Processing	
Beam Section Results	No
On Demand Stress/Strain	No

TABLE 17
Model (A4) > Static Structural (A5) > Solution (A6) > Solution Information

Object Name	Solution Information
State	Solved
Solution Information	
Solution Output	Solver Output
Newton-Raphson Residuals	0
Identify Element Violations	0
Update Interval	2.5 s
Display Points	All
FE Connection Visibility	
Activate Visibility	Yes
Display	All FE Connectors
Draw Connections Attached To	All Nodes
Line Color	Connection Type
Visible on Results	No
Line Thickness	Single
Display Type	Lines

TABLE 18
Model (A4) > Static Structural (A5) > Solution (A6) > Results

Object Name	Total Deformation	X Stress	Y Stress	Z Normal Stress
State	Solved			
Scope				
Scoping Method	Geometry Selection	Path		
Geometry	All Bodies			
Path		Path		
Definition				
Type	Total Deformation	Linearized Normal Stress		
By	Time		Result Set	Time
Display Time	Last			Last
Separate Data by Entity	No			
Calculate Time History	Yes			
Identifier				
Suppressed	No			
Orientation		X Axis	Y Axis	Z Axis
Subtype		Total		
Coordinate System		Global Coordinate System		
Zero Through-Thickness Bending Stress		No		
Set Number			Last	
Results				
Minimum	0. mm			
Maximum	3.6798 mm			
Average	2.453 mm			
Minimum Occurs On	SYS\Solid			
Maximum Occurs On	SYS\Solid			
Total (Inside)		-8.9736 MPa	-12.195 MPa	-14.075 MPa
Total (Center)		0.23069 MPa	0.52474 MPa	-1.9322 MPa
Total (Outside)		8.6029 MPa	6.5188 MPa	1.5614e-002 MPa

Information	
Time	1. s
Load Step	1
Substep	1
Iteration Number	1

FIGURE 4
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

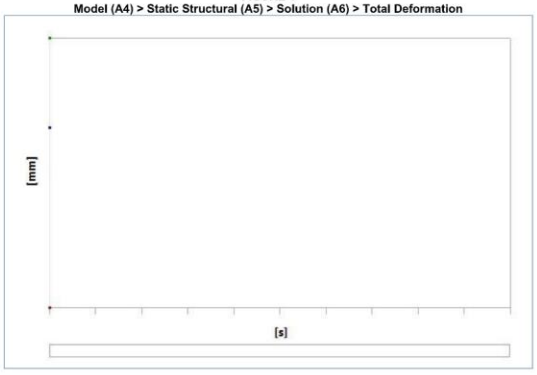


TABLE 19
Model (A4) > Static Structural (A5) > Solution (A6) > Total Deformation

Time [s]	Minimum [mm]	Maximum [mm]	Average [mm]
1.	0.	3.6798	2.453

FIGURE 5
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

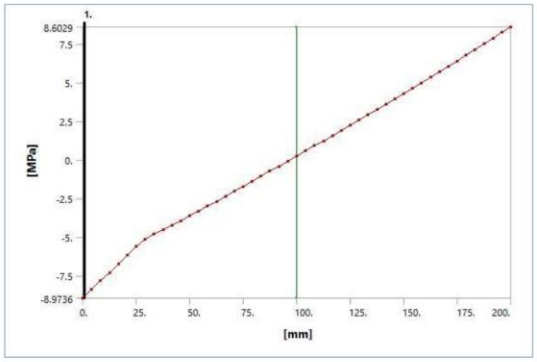


TABLE 20
Model (A4) > Static Structural (A5) > Solution (A6) > X Stress

Length [mm]	Total [MPa]
0.	-8.9736
4.1667	-8.4184
8.3333	-7.8633
12.5	-7.3081
16.667	-6.7529
20.833	-6.1978
25.	-5.6426
29.167	-5.1467
33.333	-4.8489
37.5	-4.5505
41.667	-4.2504
45.833	-3.9489
50.	-3.646
54.167	-3.3348
58.333	-3.0134
62.5	-2.6923
66.667	-2.3699
70.833	-2.0449
75.	-1.7227
79.167	-1.4051
83.333	-1.0763
87.5	-0.74828
91.667	-0.42183
95.833	-9.7353e-002
100.	0.23069
104.17	0.56326
108.33	0.89591
112.5	1.2286
116.67	1.5614
120.83	1.8944
125.	2.231

129.17	2.5722
133.33	2.9134
137.5	3.2546
141.67	3.5959
145.83	3.9371
150.	4.2823
154.17	4.635
158.33	4.9877
162.5	5.3404
166.67	5.6931
170.83	6.0459
175.	6.4011
179.17	6.768
183.33	7.135
187.5	7.502
191.67	7.869
195.83	8.236
200.	8.6029

FIGURE 6
Model (A4) > Static Structural (A5) > Solution (A6) > Y Stress

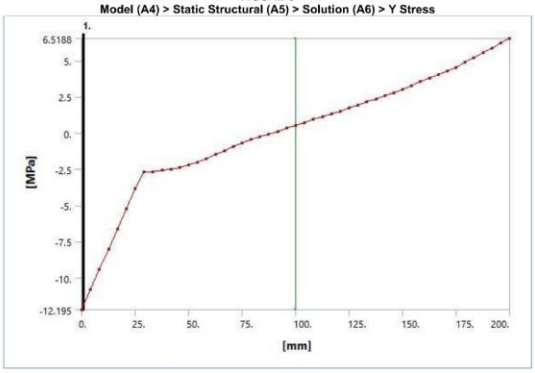


TABLE 21
Model (A4) > Static Structural (A5) > Solution (A6) > Y Stress

Length [mm]	Total [MPa]
0.	-12.195
4.1667	-10.799
8.3333	-9.4026
12.5	-8.0067
16.667	-6.6107
20.833	-5.2147
25.	-3.8188
29.167	-2.7067
33.333	-2.6615
37.5	-2.579

41.667	-2.4784
45.833	-2.3611
50.	-2.2287
54.167	-2.0327
58.333	-1.7609
62.5	-1.4887
66.667	-1.2184
70.833	-0.95443
75.	-0.69138
79.167	-0.4734
83.333	-0.28995
87.5	-0.10323
91.667	9.66e-002
95.833	0.31283
100.	0.52474
104.17	0.72116
108.33	0.91769
112.5	1.1143
116.67	1.3111
120.83	1.5077
125.	1.7126
129.17	1.9273
133.33	2.1421
137.5	2.3569
141.67	2.5717
145.83	2.7866
150.	3.0146
154.17	3.2683
158.33	3.5221
162.5	3.7759
166.67	4.0297
170.83	4.2834
175.	4.5502
179.17	4.8783
183.33	5.2064
187.5	5.5345
191.67	5.8626
195.83	6.1907
200.	6.5188

FIGURE 7
Model (A4) > Static Structural (A5) > Solution (A6) > Z Normal Stress

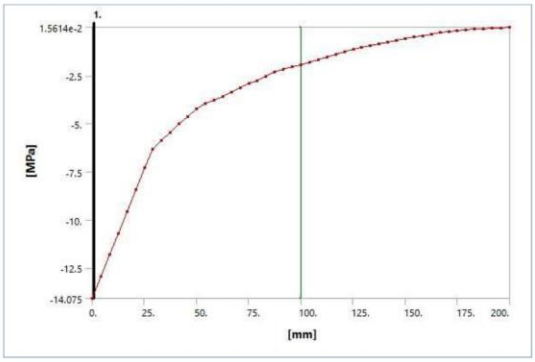


TABLE 22
Model (A4) > Static Structural (A5) > Solution (A6) > Z Normal Stress

Length [mm]	Total [MPa]
0.	-14.075
4.1667	-12.946
8.3333	-11.817
12.5	-10.688
16.667	-9.5591
20.833	-8.4302
25.	-7.3013
29.167	-6.344
33.333	-5.8681
37.5	-5.4337
41.667	-5.0162
45.833	-4.6141
50.	-4.2262
54.167	-3.9327
58.333	-3.757
62.5	-3.5758
66.667	-3.3754
70.833	-3.1432
75.	-2.9145
79.167	-2.7433
83.333	-2.5259
87.5	-2.3254
91.667	-2.1614
95.833	-2.0421
100.	-1.9322
104.17	-1.7975
108.33	-1.6629
112.5	-1.5284
116.67	-1.3941
120.83	-1.2602
125.	-1.1417

129.17	-1.0425
133.33	-0.94327
137.5	-0.84408
141.67	-0.74491
145.83	-0.64575
150.	-0.55667
154.17	-0.48738
158.33	-0.41809
162.5	-0.3488
166.67	-0.27951
170.83	-0.21022
175.	-0.14828
179.17	-0.12096
183.33	-9.3644e-002
187.5	-6.6328e-002
191.67	-3.9013e-002
195.83	-1.1699e-002
200.	1.5614e-002

TABLE 23
Model (A4) > Static Structural (A5) > Solution (A6) > Probes

Object Name	*Force Reaction*	*Deformation Probe*
State	Solved	
Definition		
Type	Force Reaction	Deformation
Location Method	Boundary Condition	Geometry Selection
Boundary Condition	Fixed Support 5	
Orientation	Global Coordinate System	
Suppressed	No	
Geometry		Defined
X Coordinate		5000.1 mm
Y Coordinate		300.02 mm
Z Coordinate		200. mm
Options		
Result Selection	All	
Display Time	End Time	
Results		
X Axis	-7.4874 N	8.6724e-004 mm
Y Axis	-7.1067 N	0.173 mm
Z Axis	4.7973e+005 N	-0.40175 mm
Total	4.7973e+005 N	0.43741 mm
Maximum Value Over Time		
X Axis	-7.4874 N	8.6724e-004 mm
Y Axis	-7.1067 N	0.173 mm
Z Axis	4.7973e+005 N	-0.40175 mm
Total	4.7973e+005 N	0.43741 mm
Minimum Value Over Time		
X Axis	-7.4874 N	8.6724e-004 mm
Y Axis	-7.1067 N	0.173 mm
Z Axis	4.7973e+005 N	-0.40175 mm
Total	4.7973e+005 N	0.43741 mm
Information		
Time	1. s	
Load Step	1	
Substep	1	
Iteration Number	1	

FIGURE 8
Model (A4) > Static Structural (A5) > Solution (A6) > Force Reaction



TABLE 24
Model (A4) > Static Structural (A5) > Solution (A6) > Force Reaction

Time [s]	Force Reaction (X) [N]	Force Reaction (Y) [N]	Force Reaction (Z) [N]	Force Reaction (Total) [N]
1.	-7.4874	-7.1067	4.7973e+005	4.7973e+005

FIGURE 9
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

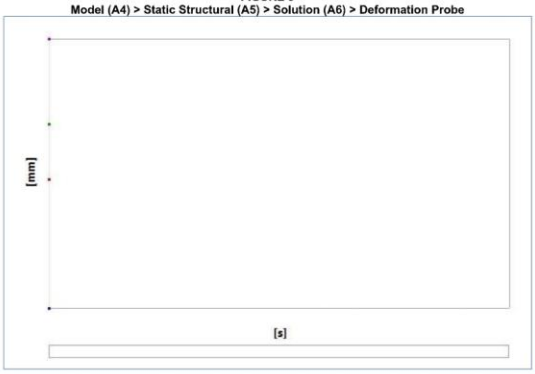


TABLE 25
Model (A4) > Static Structural (A5) > Solution (A6) > Deformation Probe

Time	Deformation Probe (X)	Deformation Probe (Y)	Deformation Probe (Z)	Deformation Probe (Total)
[s]	[mm]	[mm]	[mm]	[mm]
1.	8.6724e-004	0.173	-0.40175	0.43741

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Material Data

Concrete 2

TABLE 26
Concrete 2 > Constants

Density	2.5e-006 kg mm^-3
Coefficient of Thermal Expansion	1.4e-005 C^-1
Specific Heat	7.8e+005 mJ kg^-1 C^-1
Thermal Conductivity	7.2e-004 W mm^-1 C^-1

TABLE 27
Concrete 2 > Color

Red	Green	Blue
180	173	167

TABLE 28
Concrete 2 > Compressive Ultimate Strength

Compressive Ultimate Strength MPa
30

TABLE 29
Concrete 2 > Compressive Yield Strength

Compressive Yield Strength MPa
0

TABLE 30
Concrete 2 > Tensile Yield Strength

Tensile Yield Strength MPa
0

TABLE 31
Concrete 2 > Tensile Ultimate Strength

Tensile Ultimate Strength MPa
2.9

TABLE 32
Concrete 2 > Isotropic Secant Coefficient of Thermal Expansion

Zero-Thermal-Strain Reference Temperature C
22

TABLE 33
Concrete 2 > Isotropic Elasticity

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	Temperature C
32800	0.2	18222	13667	