British Columbia Institute of Technology

Final Report

Endura-Form Finite-Element Stress Analysis

Prepared by

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April 2008

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1.0 Determination of Modulus of Elasticity

Values for certain mechanical properties are required for performing the computer modeling. One of these properties is the Modulus of Elasticity or Young's Modulus (E) and is a measure of stiffness. In the case of the Endura Form panels, it is used to predict the amount of load before yield, the panel can support when a load is centrally placed on the panel with only the ends of the panel being supported.

The Endura Form panels are made of High Density Polyethylene (HDPE) and are constructed in an injection molding process.

The computer modeling was run with values obtained for Dow HDPE 10462N High Density Polyethylene from the MatWeb Online Materials Database.

Table 1 – MatWeb Material Properties of Dow HDPE 10462N High Density Polyethylene

Physical Properties	**Metric**	**English**
Density	0.962 g/cc	0.0348 lb/in3
Mechanical Properties		
Tensile Strength, Yield	23.4 MPa	3390 psi
Modulus of Elasticity	0.745 GPa	108 ksi

To confirm that the values obtained from Mat Web were close to the characteristics of the actual panel, samples were cut from the panel ribs and tensile tested at +23 degrees Celsius to determine the Modulus of Elasticity.

Table 2 – Material Properties of Endura Form Panels at +23^{o} Celsius

Sample Number	**Modulus of Elasticity (GPa)**	**difference from MatWeb value**
1	0.733	-1.6%
2	0.761	+2.1%

Test results show some variation in values but not of any significance to warrant any changes to the model.

To design for different environmental condition that the panels might undergo, further samples were tested at – 40 degrees Celsius and + 60 degrees Celsius.

Table 3 – Material Properties of Endura Form Panels at -40^{o} Celsius

Temperature	**Modulus of Elasticity (GPa)**[1]	**Tensile Strength, Yield (MPa)**
-40 degrees Celsius	0.799	22.7

There is no appreciable difference between the values for the Modulus of Elasticity at +23 degrees Celsius than at -40 degrees Celsius. The panel will perform similarly through the temperature range of -40 degrees Celsius through to + 23 degrees Celsius.

Table 4 – Material Properties of Endura Form Panels at +60^{o} Celsius

Temperature	**Modulus of Elasticity (GPa)**[2]	**Tensile Strength, Yield (MPa)**
+ 60 degrees Celsius	0.128	17.9

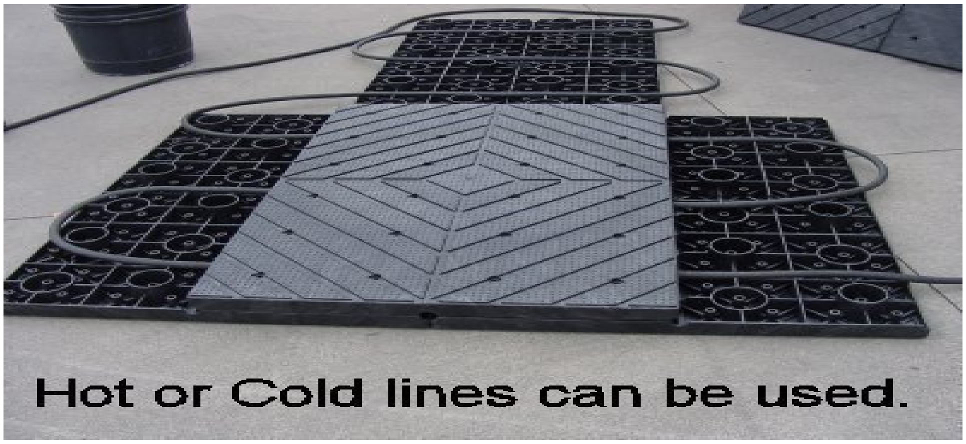
At elevated temperatures there is a significant drop in the Modulus of Elasticity which is not unexpected as the panels will soften as the temperature rises, as well as a drop in the yield stress point.

2.0 Endura HDPE Panel Stress Analysis Load Cases

Geometry/Material:

Endura panels are made out of HDPE (High Density Polyethylene) polymers. They have complex features which give them large loading capacity. The panel shape is rectangular (48”x32”) similar to a slab and can carry in-plane and/or out-of-plane loads. The panels can be locked together to increase their loading capacity. The Young’s modulus of elasticity is 745 MPa , density 962 kg/m^3 and the tensile strength yield point is 23.4 MPa.

[1] The Tangent Modulus, as reported.
[2] The Tangent Modulus, as reported.



Objective of the Analysis:

In order to quantify the loading capacity[3] of the panels, we used FEA (Finite Element Analysis) technique to calculate the mechanical stresses due to un-factored applied loads. We considered three loading cases, per client's specifications. Each load case and the obtained results are presented in the following sections. Table 1 summarizes these results. For these analyses two panels were considered when they are locked together, as shown in the picture. Data for the load cases can be seen in Appendix B.

Loading case 1:

An area at the centre of the panel is uniformly loaded. The area of the applied load is 152.4X508 mm^2 (6"X20"). The panel is loaded until the principal stress[4] reaches the yield point. For this case the loading capacity was 500 kPa, equivalent to 8700 lbs, when the panel is supported along the length and 300 kPa, equivalent to 5222 lbs when it is supported along the width.

Loading case 2:

An area at the centre of the panel is uniformly loaded. The area of the applied load is 304.8X508 mm^2 (12"X20"). The panel is loaded until the principal stress reaches the yield point. For this case the loading capacity was 260 kPa, equivalent to 9050 lbs when the panel is supported along the length and 200 kPa , equivalent to 6960 lbs when it is supported along the width.

[3] These are not design loads. For applications of these panels standard code parameters should be applied relevant to the application case.
[4] Or Von-Mises stress

Loading case 3:

The whole panel is uniformly loaded. The area of the applied load is 812.8x1219.2 mm^2 (32”X48”). The panel is loaded until the principal stress reaches the yield point. For this case the loading capacity was 140 kPa, equivalent to 31196 lbs, when the panel is supported along the length and 70 kPa, equivalent to 15593 lbs when it is supported along the width.

Special Loading Case

A special case when the panel is entirely supported on soil was also analyzed.
These results are under the assumption that the material is behaving elastically. In other words panel may carry more loads but the panel will deform permanently.

Also some analysis was done when the panels are reinforced by steel pipes placed freely in the groves of the panel. These pipes are 1” in diameter and have wall thickness of 0.113”. This analysis shows about 20-25% increase in the load capacity compared to cases without pipes. More detailed calculations should be done when exact load capacity is needed.

Table 5 - Analysis results for Endura panel load capacity (@ 23^{o} Celsius)

Load case 1		**Load case 2**		**Load case 3**	
Supported along the length	Supported along the width	Supported along the length	Supported along the width	Supported along the length	Supported along the width
8700 lbs (500 KPa)	5222 lbs (300 Kpa)	9050 lbs (260 KPa)	6960 lbs (200 KPa)	31196 lbs (140 KPa)	15593 lbs (70KPa)

Table 6 - Analysis results for Endura panel load capacity (@ -40^{o} Celsius)

Load Case 3
Supported along the width
15593 lbs (70 KPa)

Table 7 - Analysis results for Endura panel load capacity (@ +60^{o} Celsius)

Load case 3
Supported along the width
11138 lbs (50KPa)

3.0 Summary

The Endura Form panels, made of High Density Polyethylene lends itself to a many applications because of its wide range of characteristics, among them

- resistance to many different solvents,
- ability to withstand elevated temperatures (110 degrees Celsius continuously, albeit with a drop in load capacity)
- higher tensile strength than lower density polyethylene
- good impact resistance
- low weight (specific gravity of 0.95)
- low moisture absorption

Table 1: Analysis results for Endura panel load capacity at room temperature (23^o C), shows the maximum theoretical values of the loading of the panel before yielding or deformation takes place. This means once the load is removed, the panel will return to its original shape. For practical applications load factors and yield strength coefficients should be applied according to the relevant code of practice.

As indicated in Table 5, temperature does not play a significant role in the ability of the panel to withstand loading when the panel is loaded at 23^o Celsius or lower (tested down to -40^o C). However, as the temperature rises above 23^o Celsius (tested to $+60^o$ C), the ability of the Endura Form panels to withstand load, decreases as shown in Table 6. This shows that the material is much less “stiff” at higher temperatures (i.e. will deform more under a given load than at lower temperatures). Therefore, load capacity should be de-rated with temperature increases and design factors incorporated into the design when needed.
Testing results can be seen in Appendix A.

In the special loading case, where pipes were added into the panel structure, load capacity theoretically increased by 20-25% of the values in table 1.

Appendix A – Tensile Testing Results

Room Temperature Sample

BCIT
Plastics

PLAS 3310 - Tensile
Elongation at Specified Load : 100 lb, 200 lb
Load at Specified Elongation : 1%, 2%

Test type: Tensile
Operator name:
Sample Identification: HDPE 4
Interface Type: 1011

Instron Corporation
Series IX Automated Materials Testing System 8.09.00
Test Date: Saturday, October 11, 1997

Sample Rate (pts/secs): 10.0000
Crosshead Speed: 0.1969 in/min
2nd Crosshead Speed: 0.0000 in/min
Full Scale Load Range: 1124.045 lbf

Humidity (%): 50
Temperature: 23 C

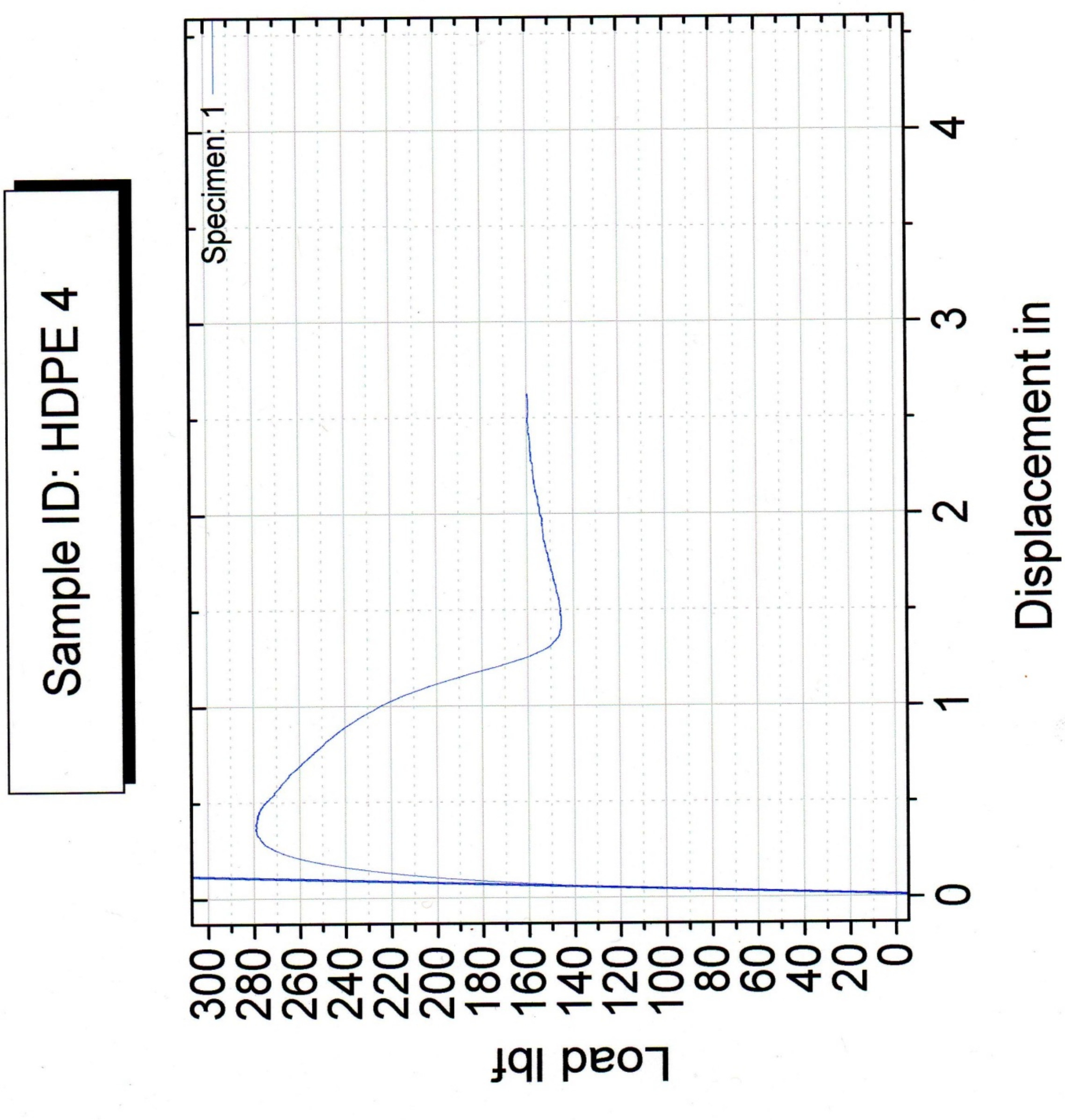
Sample comments: sample 4 jan21 08

PLAS 3310

	Displcment at Peak (in)	% Strain at Peak (%)	Load at Peak (lbf)	Stress at Peak (psi)	Displcment at Break (in)
1	0.469	14.906	276.515	3533.302	2.616
Mean	0.469	14.906	276.515	3533.302	2.616
S.D.	0.000	0.000	0.000	0.000	0.000

	Displcment at 0.2% Yield (in)	Young's Modulus (psi)	Energy at Break (lbs-in)	Tensile Energy Absorption (lbf/in)	Modulus (AutYoung) (psi)
1	0.055	120248.180	502.407	409.259	120248.180
Mean	0.055	120248.180	502.407	409.259	120248.180
S.D.	0.000	0.000	0.000	0.000	0.000

Graph of Room Temperature Sample



-40 Degree Celsius Samples

Sintech Inc. Report Date:Apr 03, 2008

Detailed Report

#7

ASTM D638 Tensile Properties of Plastics
- General Procedure -
Using Type I or Type IV dumbells
- Tested on the Instron 1130 -

Method: ASTM D638 Plastic Tensile test
Sample ID> BCIT-HDPE -40C

Test Date: Apr 03, 2008
Operator ID: COLWELL

Sample Information:

Sample Type: BCIT HDPE -40C
Project Number: xx

	Width mm	Thickness mm	Peak Stress MPa	Break Load Kg	Break Stress MPa	%Strn @ Break %	Yield Stress MPa	%Strain @ Yield %	Modulus MPa
~~1*~~	~~5.830~~	~~3.930~~	0.536	1.252	0.536	3.280	0.3	0.1	609.94
2	5.830	3.930	46.517	********* No Break	~~5.320~~	~~0.000~~	38.4	6.6	935.60
~~3*~~	~~5.830~~	~~3.930~~	4.107	*********	*********	*********	*********	*********	*********
~~4*~~	~~5.830~~	~~3.930~~	4.107	*********	*********	*********	*********	*********	*********
5	5.830	3.930	5.268	0.834 ← low break	0.357	4.224	4.2	1.3	311.17
6	5.860	3.800	19.751	22.112 "	9.738	9.304	19.6	3.0	995.02
7	5.660	3.930	30.073	16.897 "	7.449	22.216	28.6	4.6	952.26
Mean	5.795	3.898	25.402	13.281	5.718	8.936	22.7	3.9	798.51
Min	5.660	3.800	5.268	0.834	0.357	0.000	4.2	1.3	311.17
Max	5.860	3.930	46.517	22.112	9.738	22.216	38.4	6.6	995.02
StDv	0.091	0.065	17.368	11.090	4.002	9.636	14.5	2.3	325.86
%Cov	1.572	1.668	68.373	83.503	69.990	107.832	64.0	58.3	40.81
Medn	5.830	3.930	24.912	8.866	6.388	6.764	24.1	3.8	943.93

Reported

Calculation Input(s):

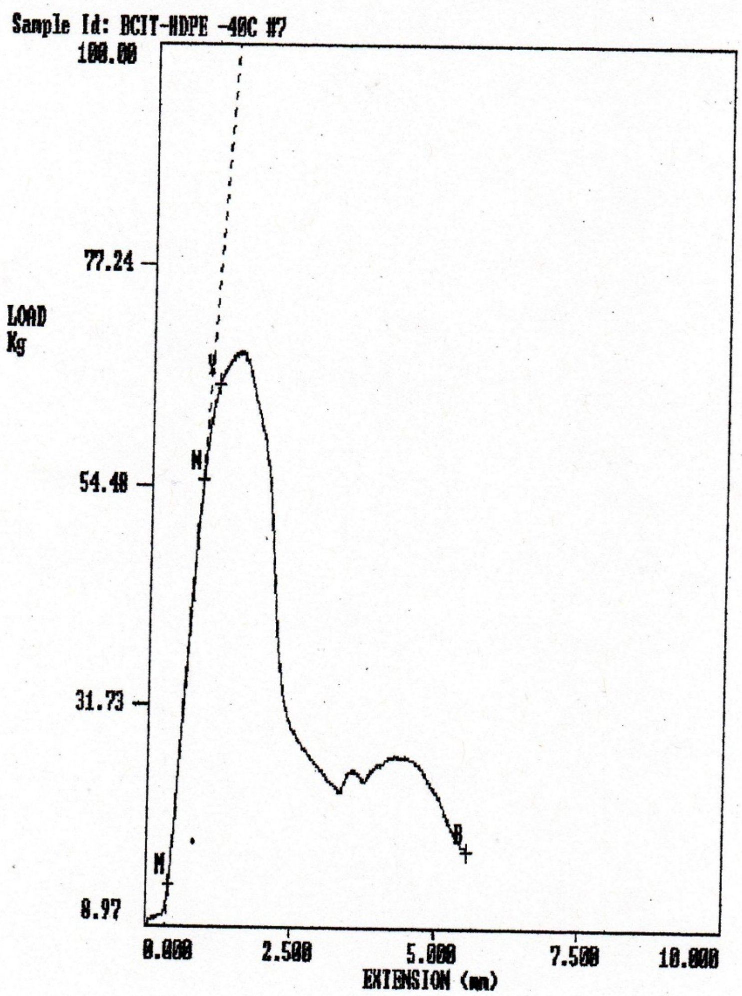
Gage Length 1 25.00 mm

Test Input(s):

Initial Speed	5.00	cm/Min
Ext Limit HI	400.0	mm
Time Limit	10000	Sec
Brk Sensitivity	75	%
Speed Change Pt	50.0	%

Comments:

Graph of -40 Degree Celsius Samples



+60 Degree Celsius Samples

Sintech Inc.

Report Date:Apr 17. 2008

Detailed Report

ASTM D638 Tensile Properties of Plastics
- General Procedure -
Using Type I or Type IV dumbells
- Tested on the Instron 1130 -

Method: ASTM D638 Plastic Tensile test
Sample ID> BCIT HDPE +60

Test Date: Apr 17. 2008
Operator ID: COLWELL

Sample Information:

(black)

Sample Type: BCIT HDPE +60 °C
Project Number: XX

	Width	Thickness	Peak Stress	Break Load	Break Stress	%Strn @ Break	Yield Stress	%Strain @ Yield	Modulus
	mm	mm	MPa	kg	MPa	%	MPa	%	MPa
* 1	~~5.720~~	~~3.930~~	~~0.273~~	~~0.834~~	~~0.364~~	~~23.440~~	~~*********~~	~~*********~~	~~0.23~~
* 2	~~5.720~~	~~3.930~~	~~10.186~~	~~23.349~~	~~10.186~~	~~10.728~~	~~9.8~~	~~8.7~~	~~149.89~~
3	5.720	3.930	20.553	11.674	5.093	178.680	19.6	15.7	178.15
4	5.720	3.890	19.019	13.759	6.064	311.808	18.4	17.2	126.82
5	5.800	3.850	17.395	13.967	6.134	365.424	17.1	20.3	101.73
6	5.790	3.840	17.011	11.883	5.241	300.392	16.5	19.8	105.77
Reported					5.72 MPa	289%	17.9 MPa	18.3%	128 MPa
Mean	5.745	3.895	13.982	12.300	~~5.392~~	~~198.412~~	~~16.3~~	~~16.4~~	~~110.43~~
Min	5.720	3.840	-0.273	-0.834	-0.364	10.728	9.8	8.7	0.23
Max	5.800	3.930	20.553	23.349	10.186	365.424	19.6	20.3	178.15
StDv	0.039	0.042	7.836	7.747	3.383	153.220	3.8	4.7	61.08
%Cov	0.676	1.074	56.042	62.982	62.737	77.223	23.3	28.6	55.31
Medn	5.720	3.910	17.203	12.821	5.653	239.536	16.8	16.4	116.30

Calculation Input(s):

Gage Length 1	25.00	mm

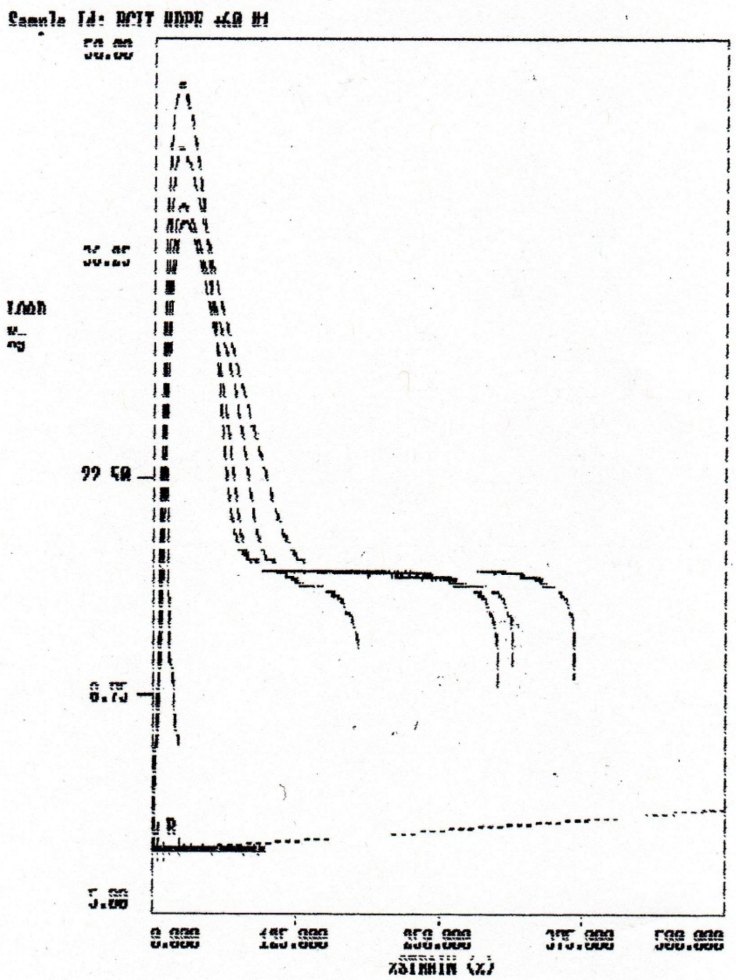
Test Input(s):

Initial Speed	5.00	cm/Min
Ext Limit HI	400.0	mm
Time Limit	10000	Sec
Brk Sensitivity	75	%
Speed Change Pt	50.0	%

Comments:

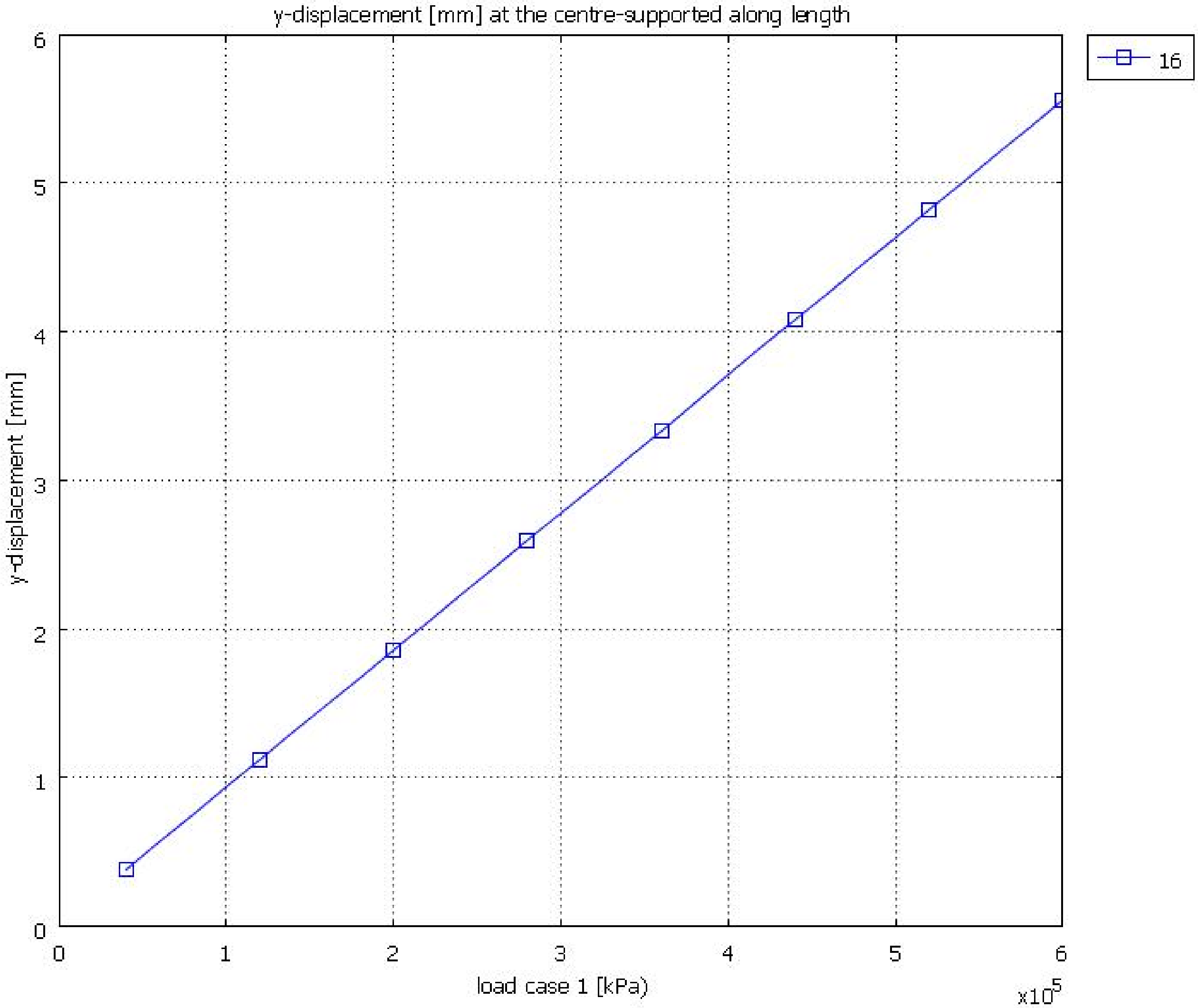
2 : Break OK

Graph of +60 Degree Celsius Samples

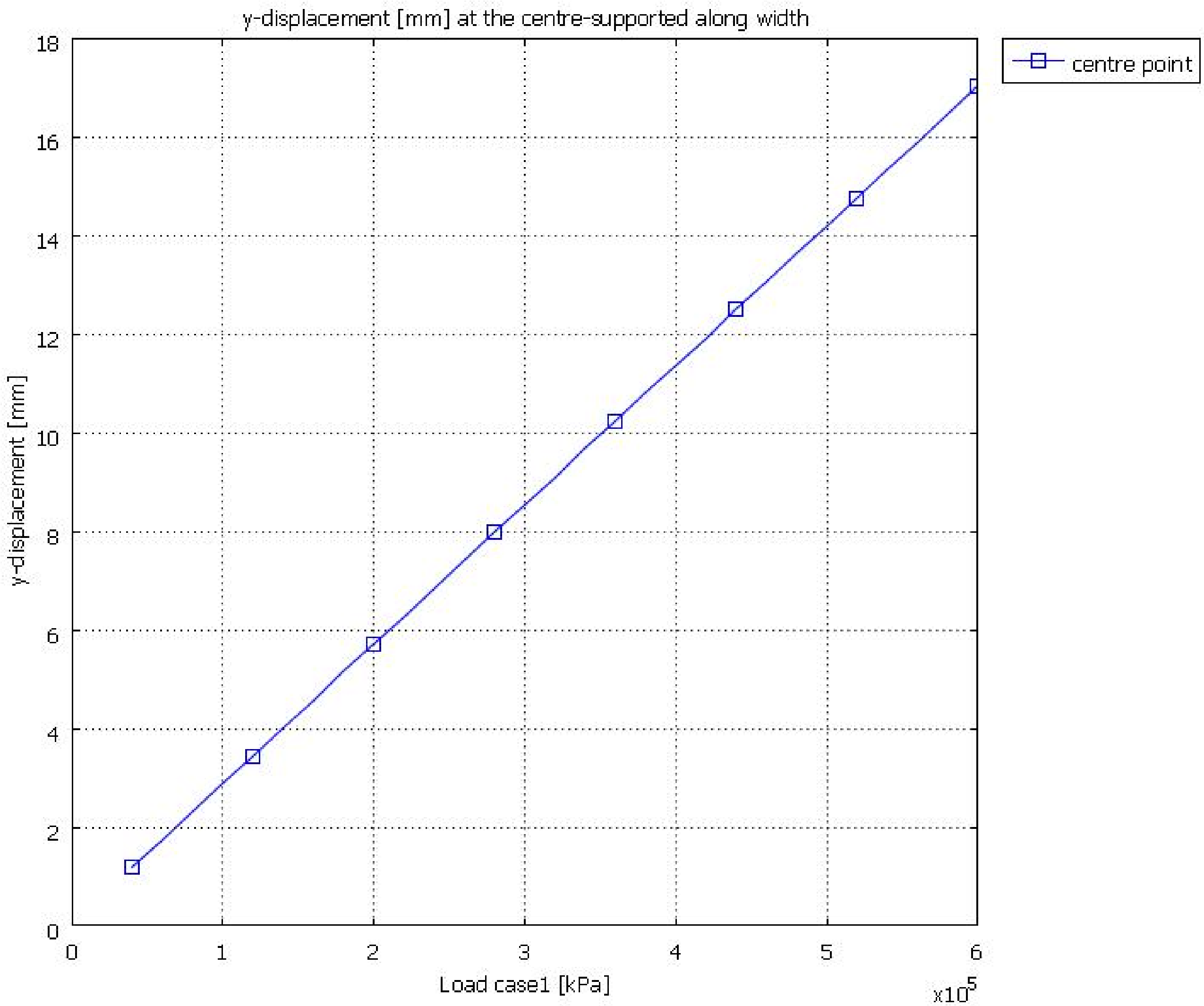


Appendix B – Finite Element Analysis

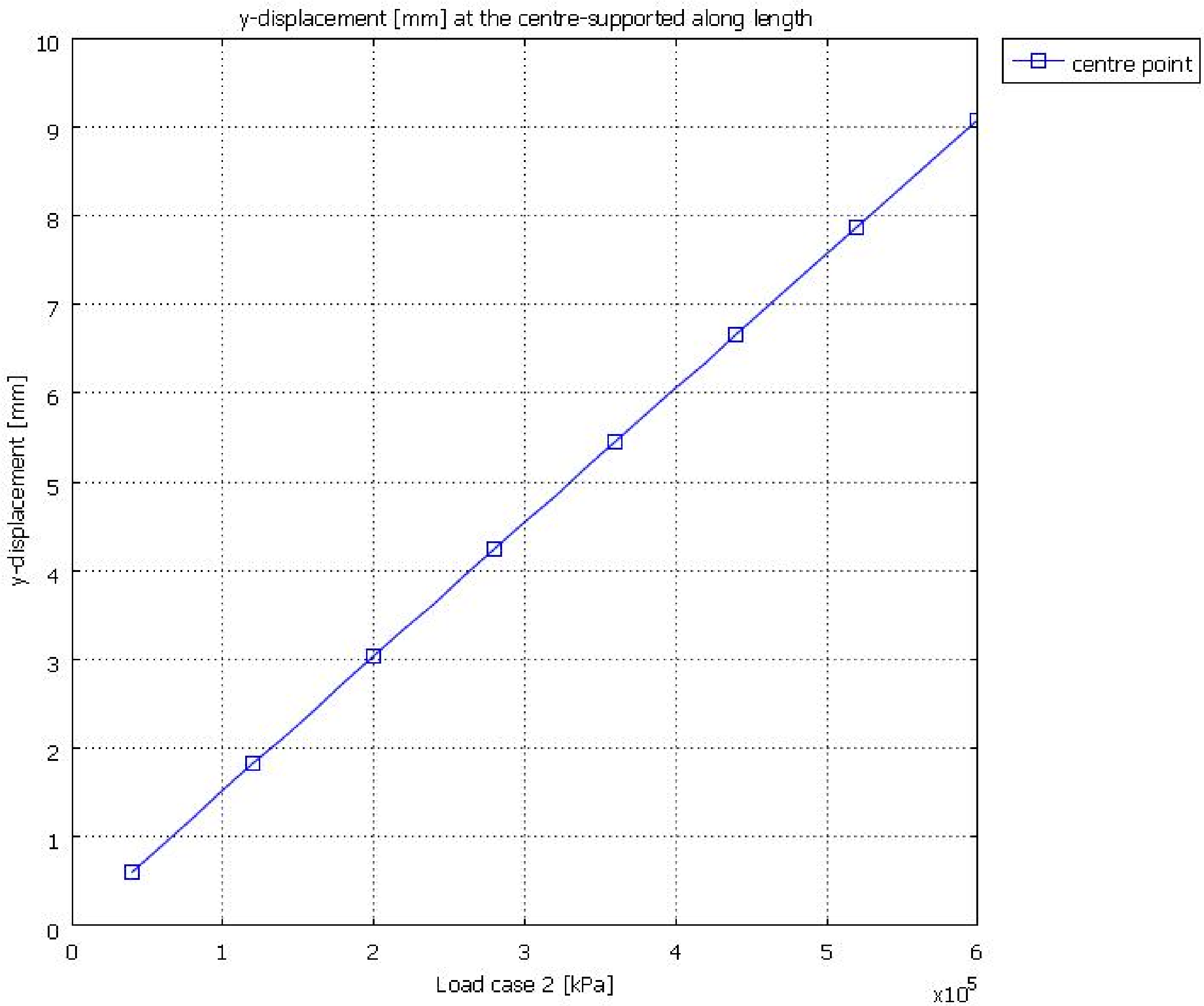
Load Case 1 – Length



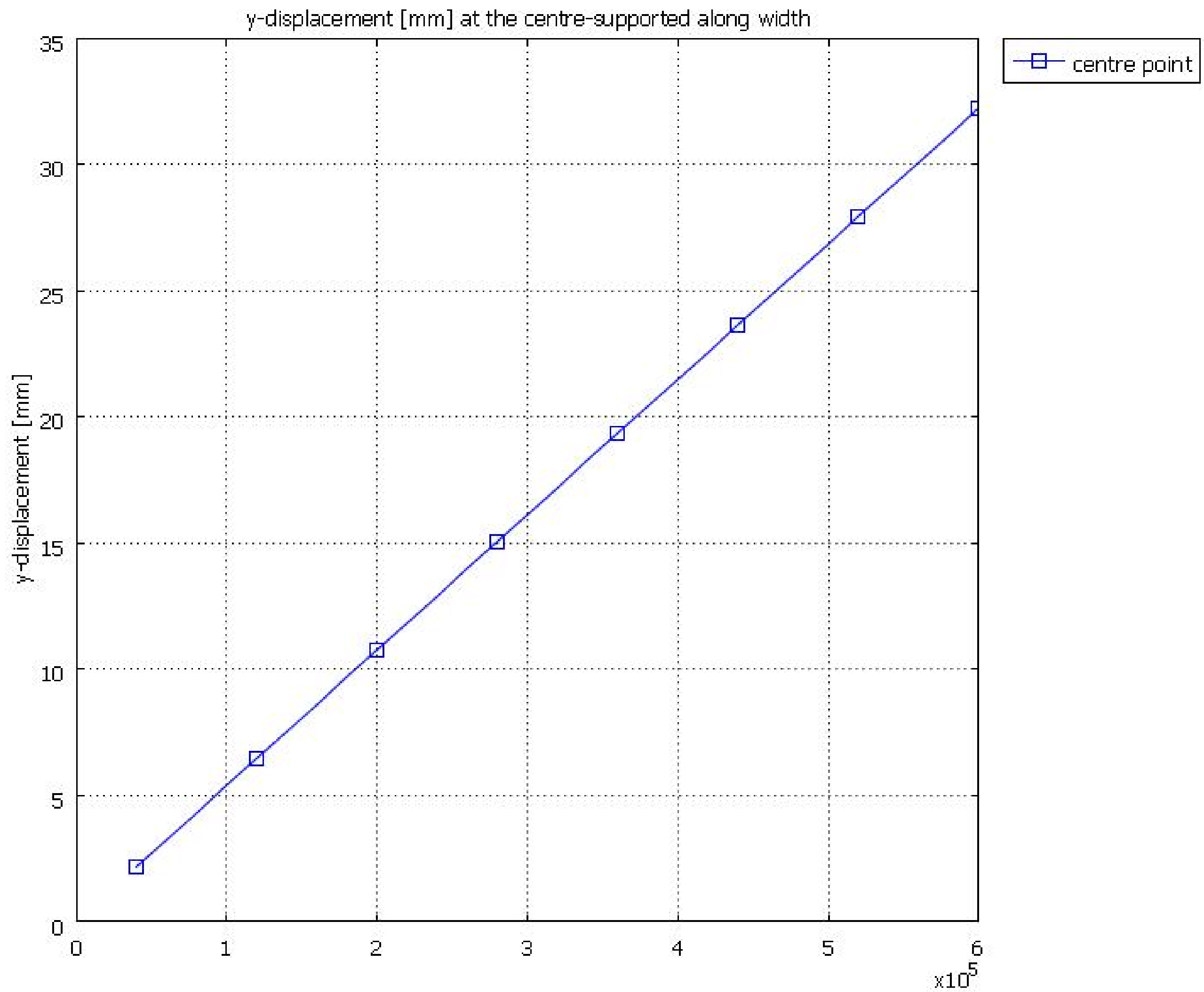
Load Case 1 – Width



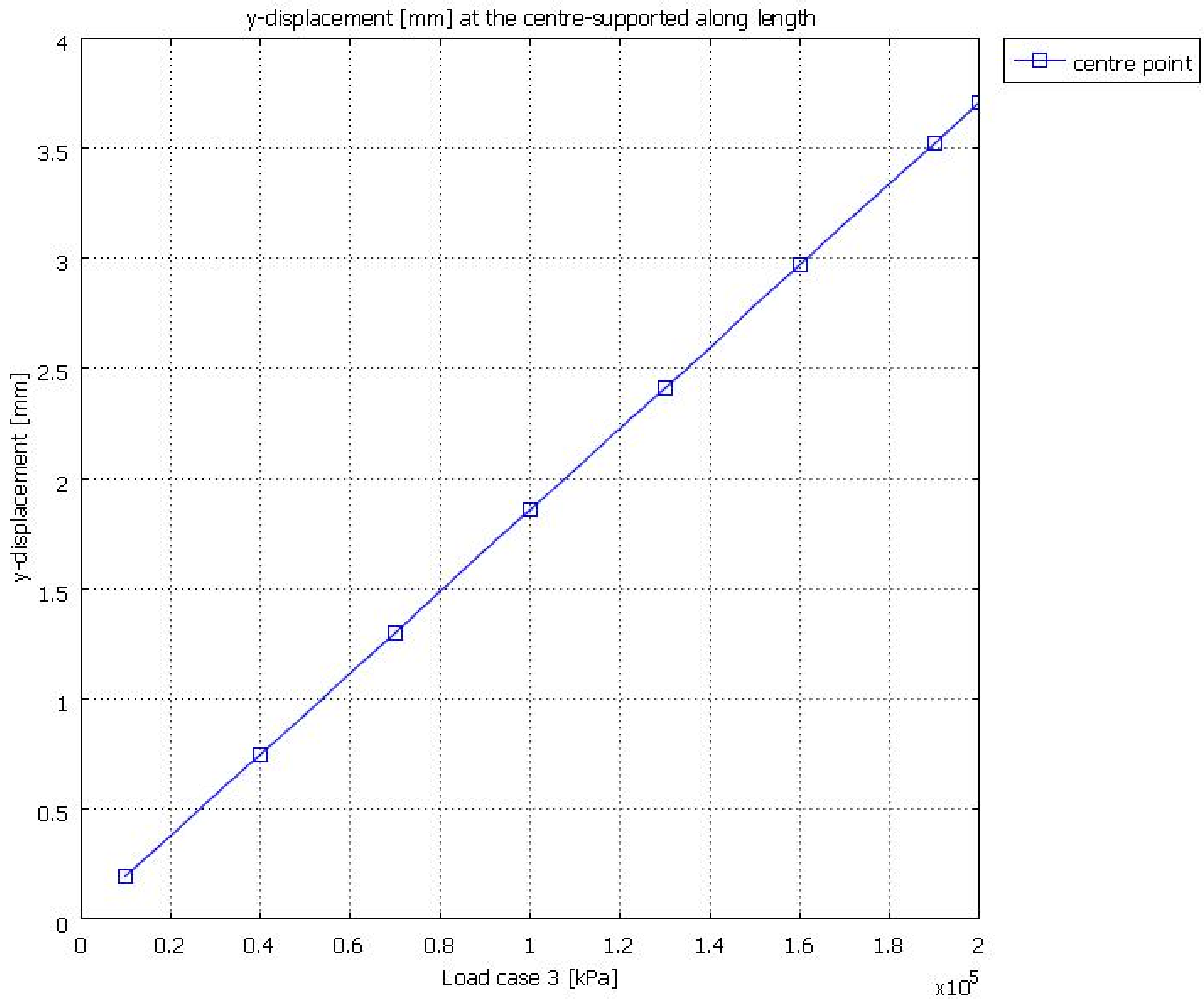
Load Case 2 – Length



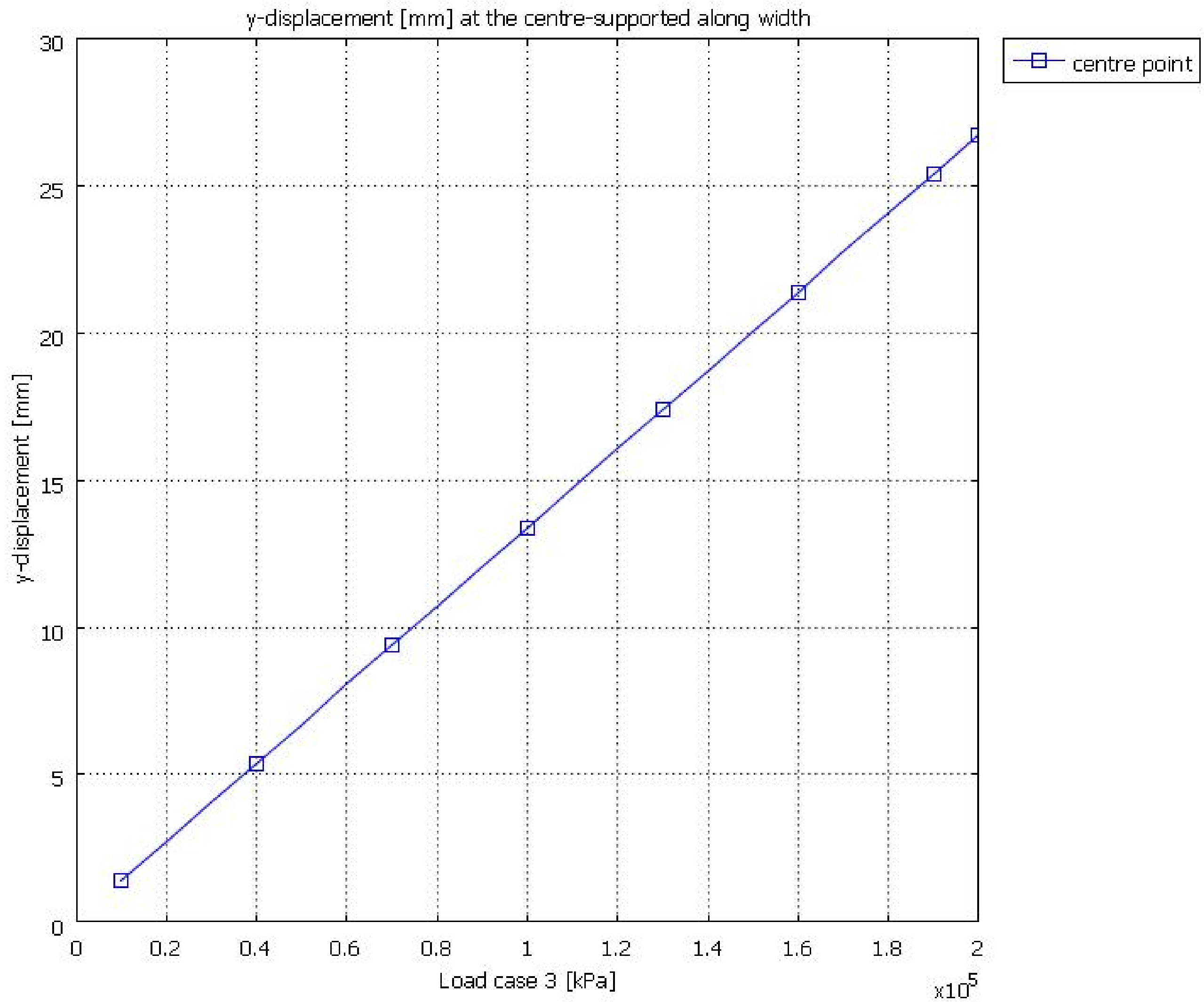
Load Case 2 – Width



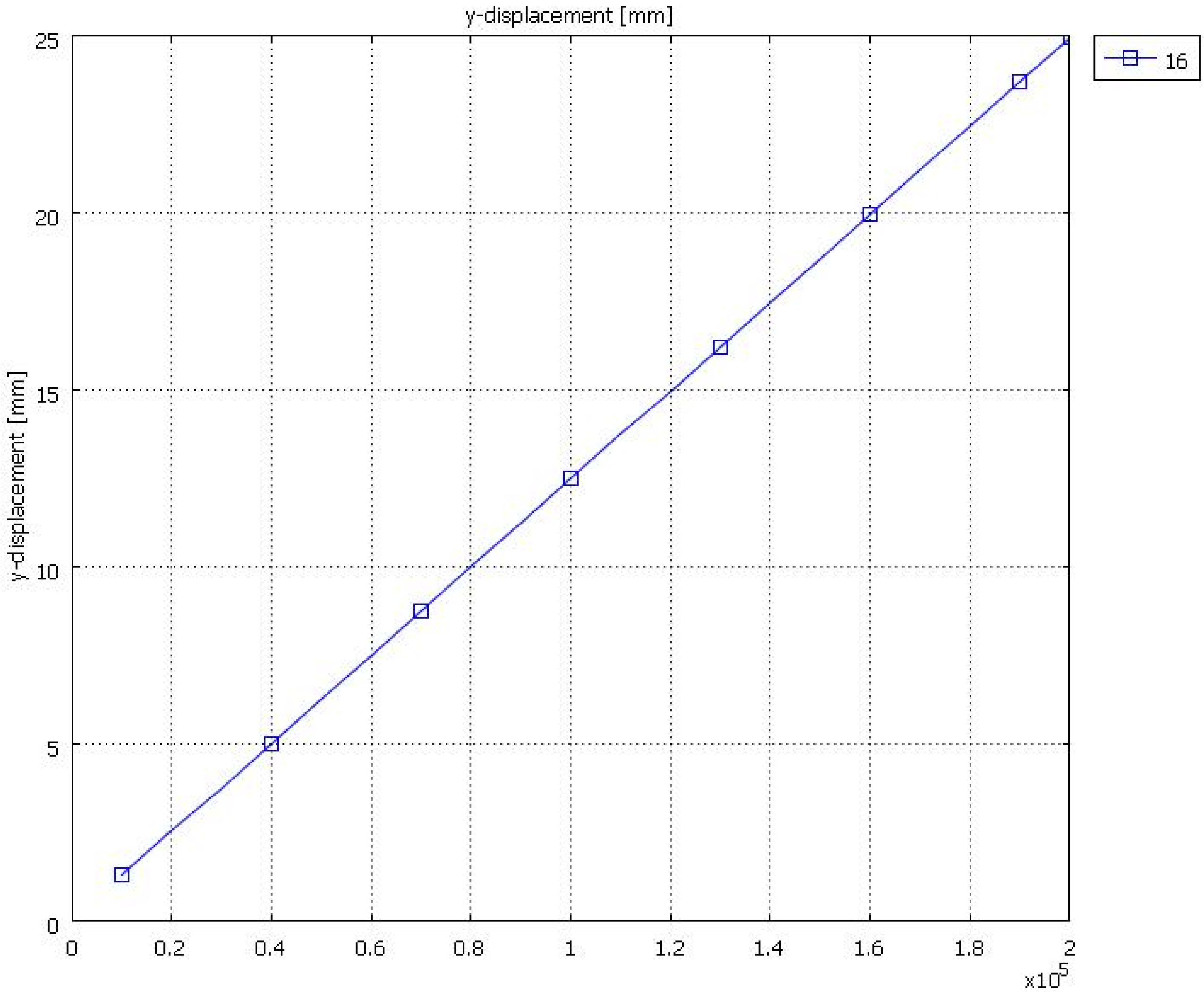
Load Case 3 – Length



Load Case 3 – Width



Load Case 2 – at -40 degrees Celsius along the width



Finite Element Analysis at -40 degrees Celsius