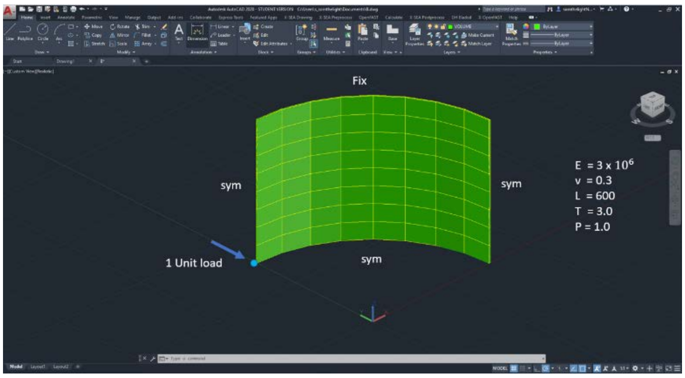
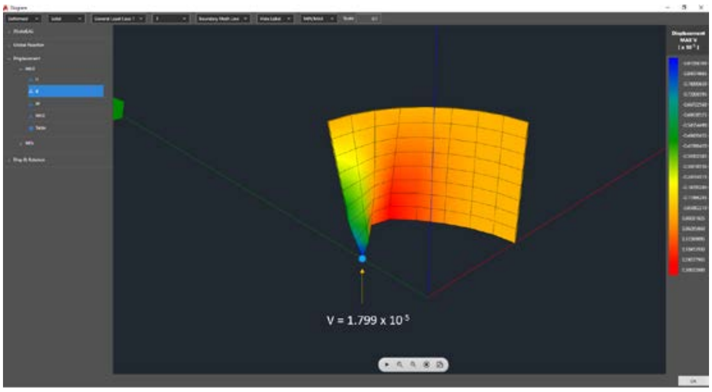
Verification report: Xsolid: 2021-09-18

AutoCAD Embedded Finite Element Structural Analysis
Software for Offshore & Onshore Structure

"X-SEA AutoCAD"

Verification Report of 3-D 8-node Solid element (XSolid)





KOREA UNIVERSITY

Professor Goangseup Zi
Structural Engineering & Mechanics Lab.
Department of Civil Engineering
Korea University, Seoul, Korea

Verification Example of X-SEA AutoCAD	No: Solid 001

Title: Cook's Membrane Problem

Problem Description

The Cook's membrane problem shown in Figure 1 is solved to determine the sensitivity of finite elements to geometric distortion of the current element on a flat surface. This is a situation that involves a significant amount of shear deformation; it is used to demonstrate the element's capability in modeling membrane deformation.

thickness t = 0.1; E = 1.0; ν = 0.3. Loading F = 1.0.

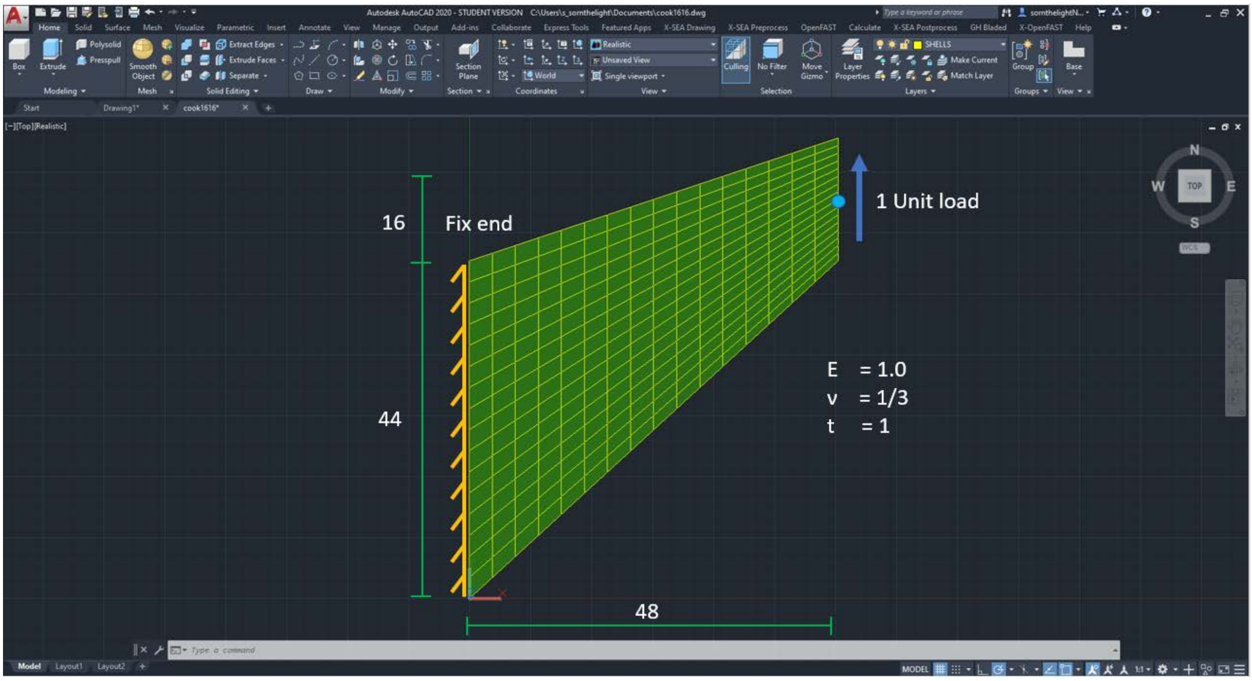


Fig.1.1 Cook's membrane Model

Results

In Table 1.1, numerical results are listed with the vertical displacement at the tip (reference solution = 23.91). The current element performs admirably.

Table 1.1 Result of Cook's Membrane Problem (V = 23.91)

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
2x2x1	20.870	0.873
4x4x1	23.051	0.964
8x8x1	23.809	0.996
16x16x1	24.791	1.037

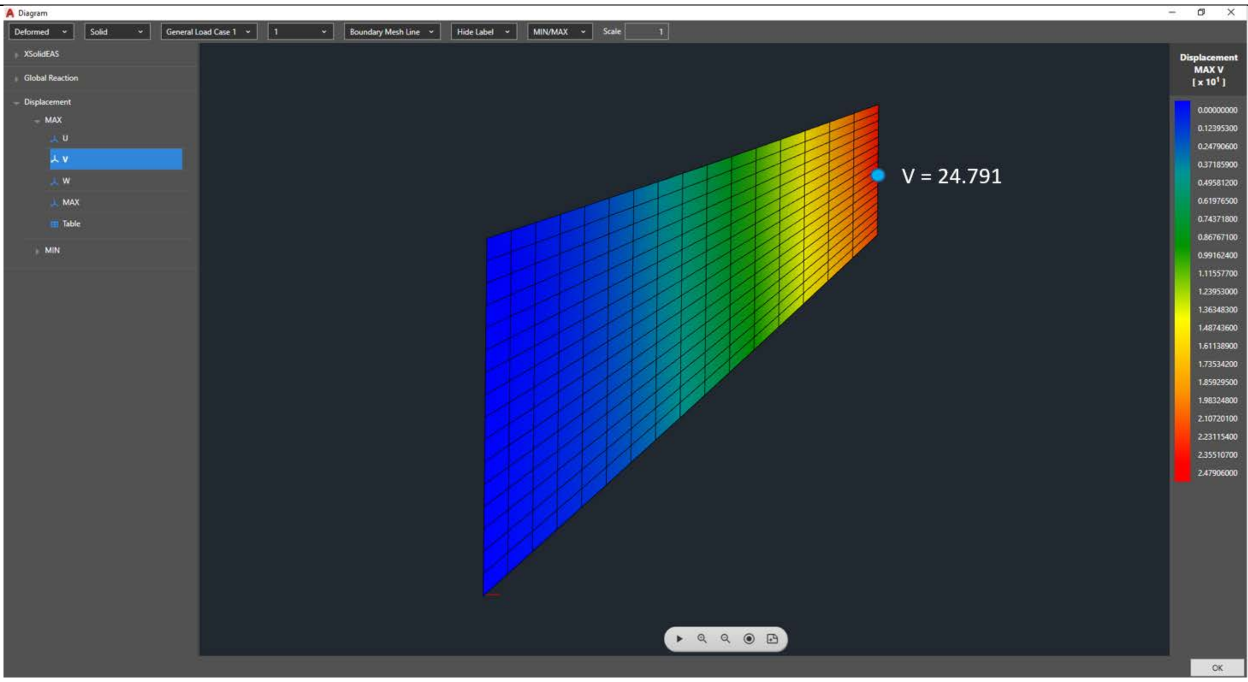


Fig.1.2 Deformation of Cook's membrane model

Verification Example of X-SEA AutoCAD	No: Solid 002

Title: Curved beam problem (In-Plane)

Problem Description

In Figure 2.1, the curve beam problem is subjected to an in-plane shear tip force. Due to the inherent mesh distortion, this problem can be used to investigate the effect of slight irregularity in the element geometry. The present result demonstrates the proposed element's superior performance.

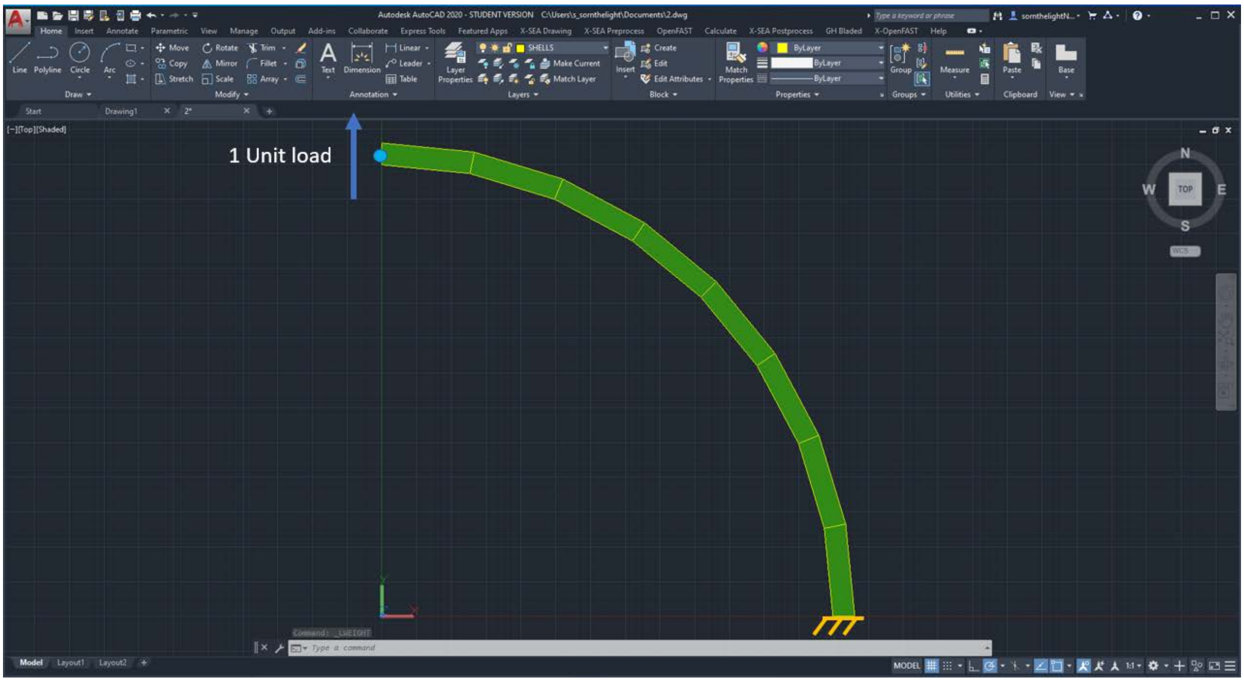


Fig. 2.1 Curved beam problem (In-Plane) Model

Results

The analytical vertical displacement solution at free end and the finite element solutions by X-SEA is show in the picture follows.

Table 2.1 Result of curved beam under in-plane shear (V = 0.08734)

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
6x1x1	0.076870	0.880
8x1x1	0.084132	0.963
12x1x1	0.087296	0.999

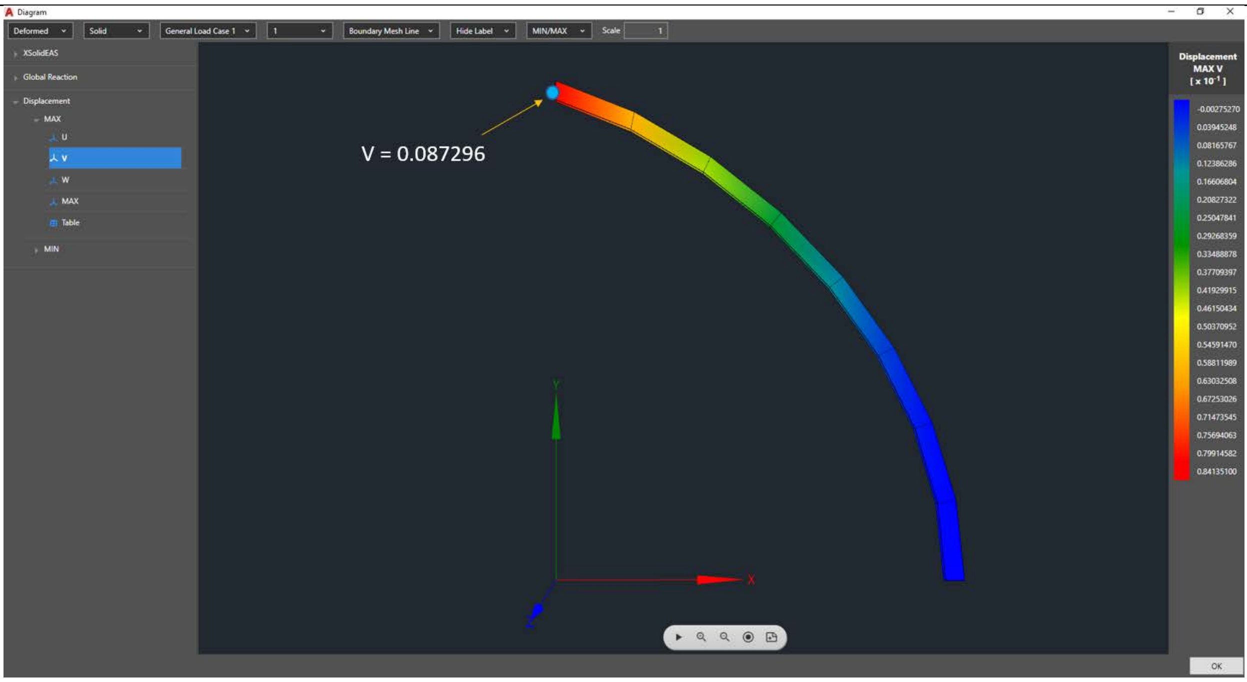


Fig.2.2 Deformation of Curved beam problem result (In-Plane) Model

Verification Example of X-SEA AutoCAD	No: Solid 003

Title: Curved beam problem (Out-Plane)

Problem Description

In Figure 3.1, the curved beam problem is subjected to an out-of-plane shear tip force. Due to the inherent mesh distortion, this problem can be used to investigate the effect of minor irregularity in element geometry. The present results demonstrate the proposed element's superior performance.

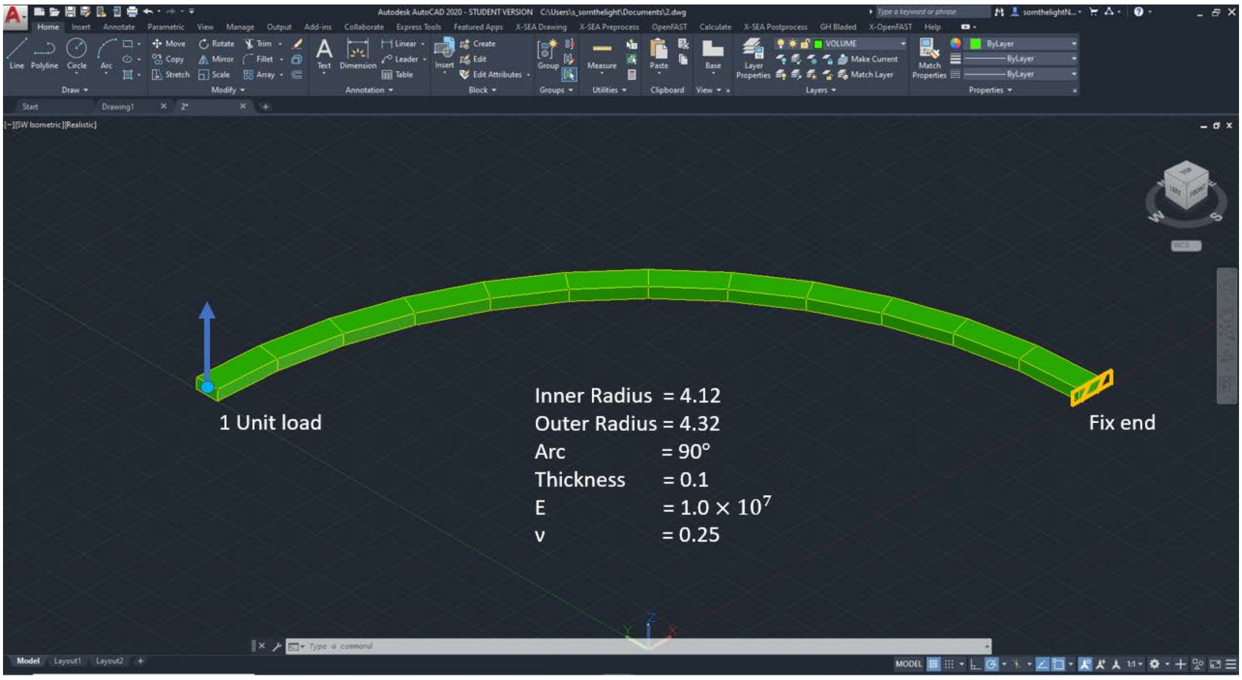


Fig. 3.1 Curved beam problem (Out-Plane) Model

Results

The analytical out-plane displacement solution at free end and the finite element solutions by X-SEA is show in the picture follows.

Table 3.1 Result of curved beam under out-plane shear (W = 0.5022)

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
6x1x1	0.42482	0.846
8x1x1	0.46180	0.920
12x1x1	0.47844	0.953

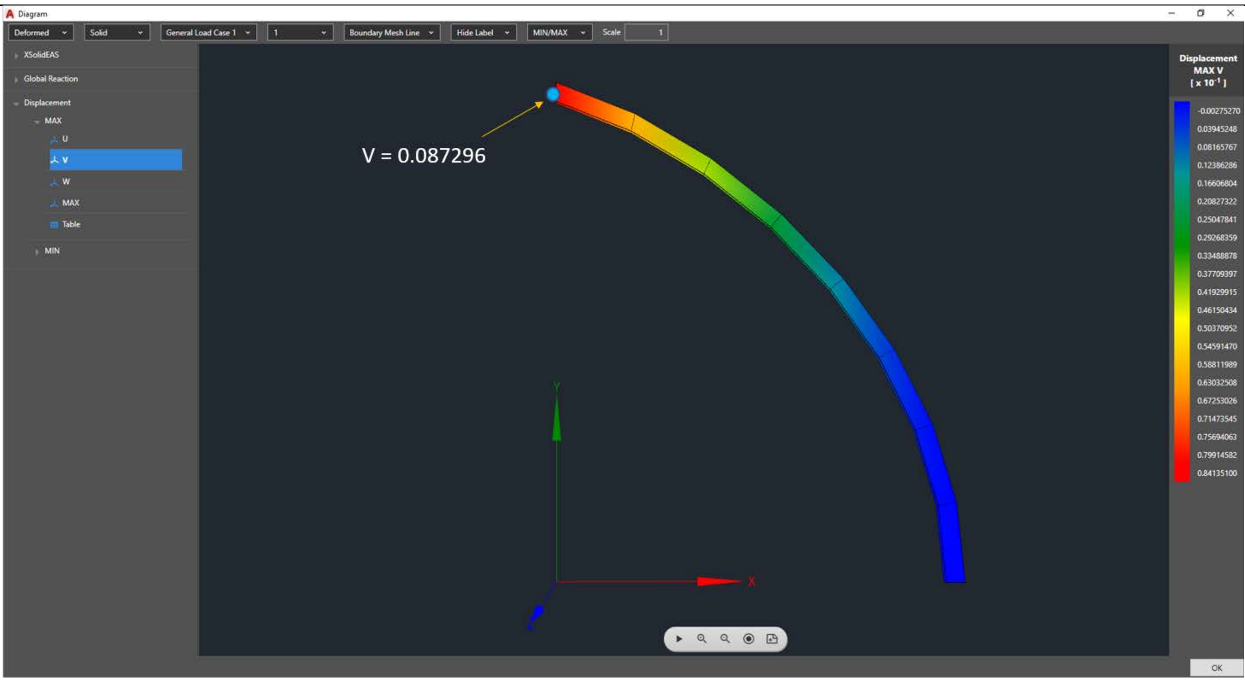


Fig.3.2 Deformation of Curved beam problem (Out-Plane) Model

Verification Example of X-SEA AutoCAD	No: Solid 004
Title: Twist Beam	
Problem Description	

To investigate the effect of element warping, the twisted beam problem is proposed. The shear forces acting on elements with a thickness of 0.32 and 0.0032 are investigated in-plane and out-of-plane. The present results demonstrate the current solid element's superior performance.

(a) For the case of thickness t = 0.32, In-Plane shear
Under in-plane shear force at the free end, the analytic solution deflection of free end is 0.005424.

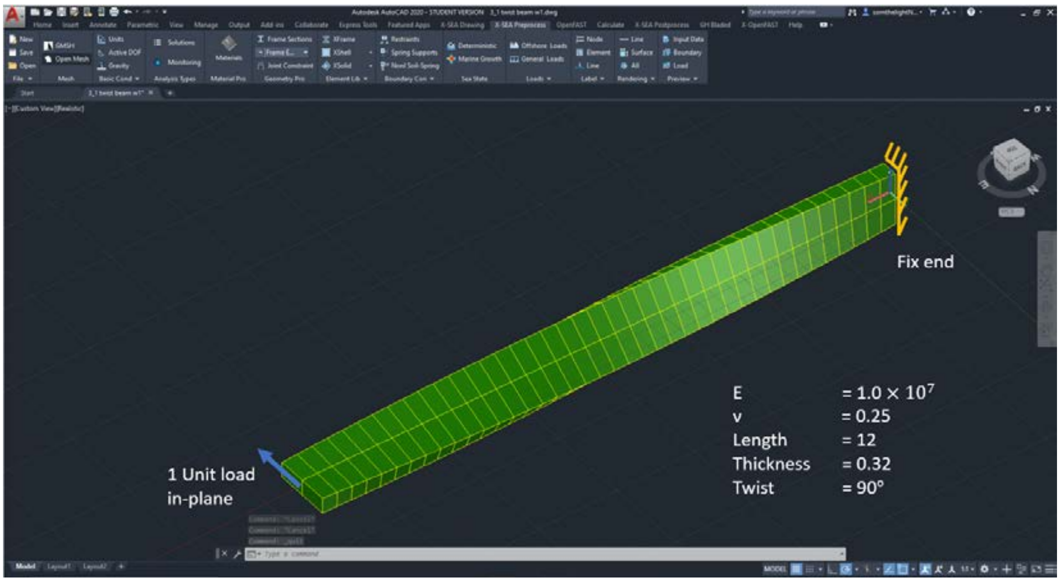


Fig. 4.1 Twist Beam with 0.32 thickness against in-plane unit load Model

(b) For the case of thickness t = 0.32, Out-of-plane Shear
Under Out-plane shear force at the free end, the analytic solution deflection of free end is 0.001754.

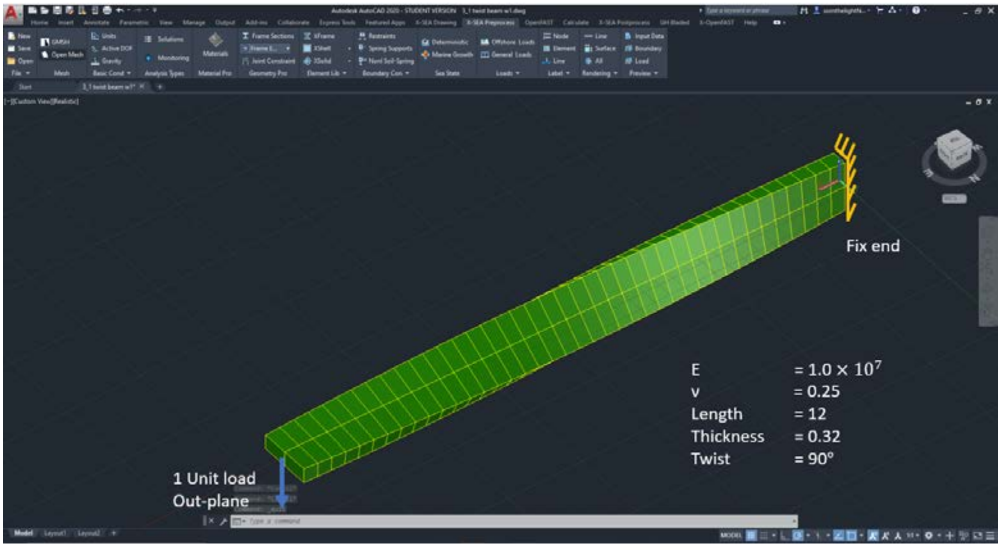


Fig. 4.2 Twist Beam with 0.32 thickness against out-plane unit load Model

(c) For the case of thickness t = 0.0032, In-Plane Shear

Under Out-plane shear force at the free end, the analytic solution deflection of free end is $0.5256x10^4$.

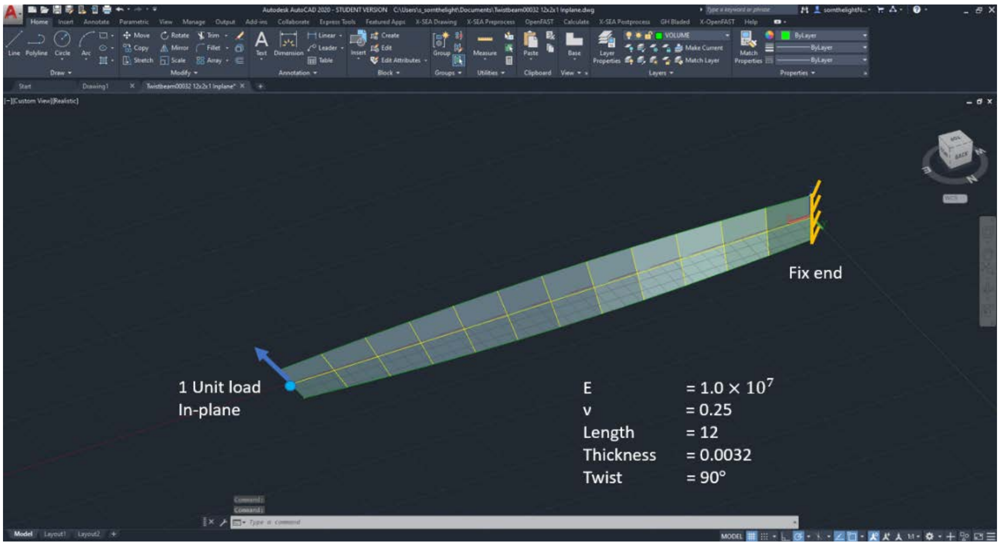


Fig. 4.3 Twist Beam with 0.0032 thickness against in-plane unit load Model

(d) For the case of thickness t = 0.0032, Out-Plane shear

Under Out-plane shear force at the free end, the analytic solution deflection of free end is $0.1294x10^4$.

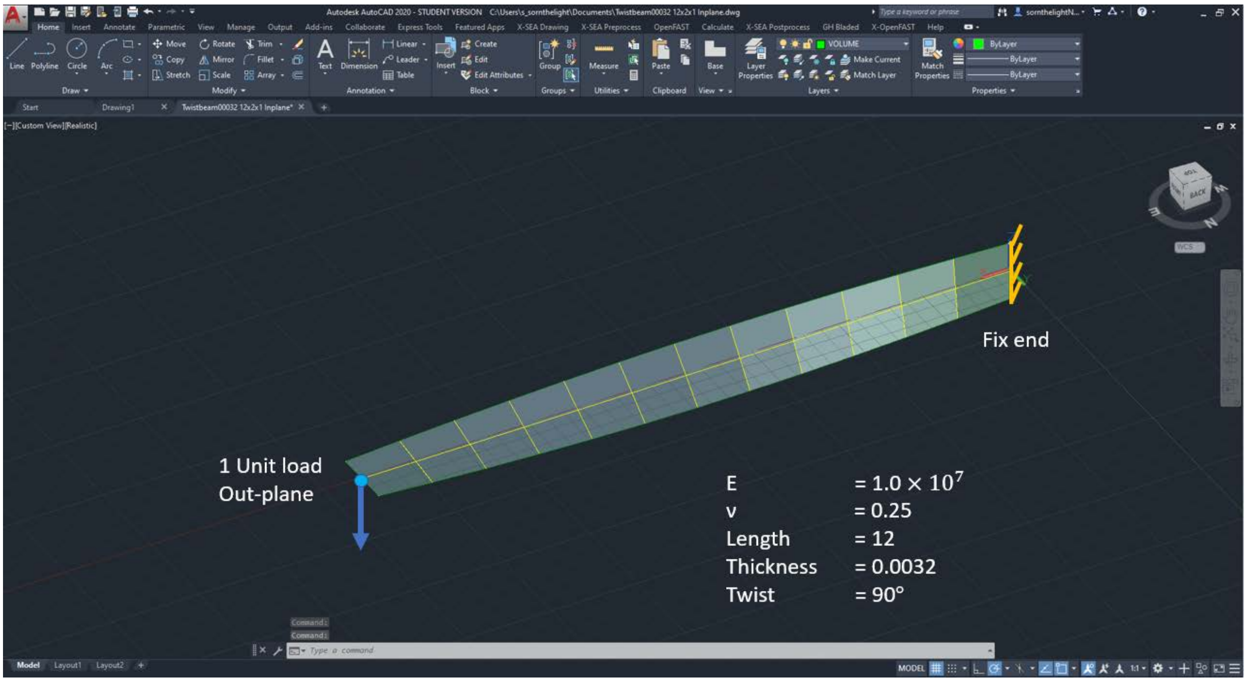


Fig. 4.4 Twist Beam with 0.0032 thickness against in-plane unit load Model

Results

The analytical vertical displacement solution at center and the finite element solutions by X-SEA using a 8x8x1 mesh is show in the picture follows.

(a) For the case of thickness t = 0.32, In-Plane shear
Under in-plane shear force at the free end, the analytic solution deflection of free end is 0.005424.

Table 4.1 Result of Twisted Beam with thickness = 0.32 In-plane (V =5.424 x 10^{-3})

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
4x2x1	$5.416x10^{-3}$	0.998
8x2x1	$5.417x10^{-3}$	0.999
12x2x1	$5.420x10^{-3}$	0.999
40x2x1	$5.423x10^{-3}$	1.000

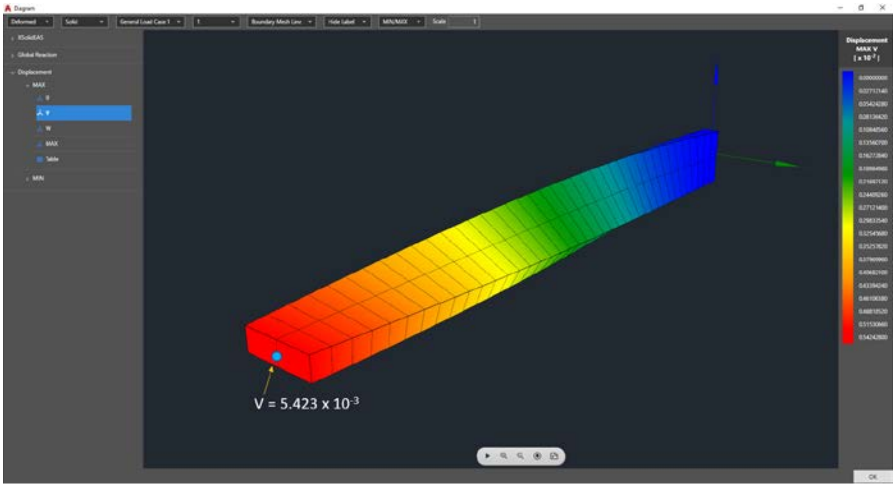


Fig. 4.5 Deformation of Twist Beam with 0.32 thickness against in-plane unit load Model

(b) For the case of thickness t = 0.32, Out-of plane Shear
Under Out-plane shear force at the free end, the analytic solution deflection of free end is 0.001754.

Table 4.2 Result of Twisted Beam with thickness = 0.32 Out-plane (V =1.754 x 10^{-3})

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
4x2x1	$1.650x10^{-3}$	0.940
8x2x1	$1.724x10^{-3}$	0.983
12x2x1	$1.738x10^{-3}$	0.991
40x2x1	$1.750x10^{-3}$	0.998

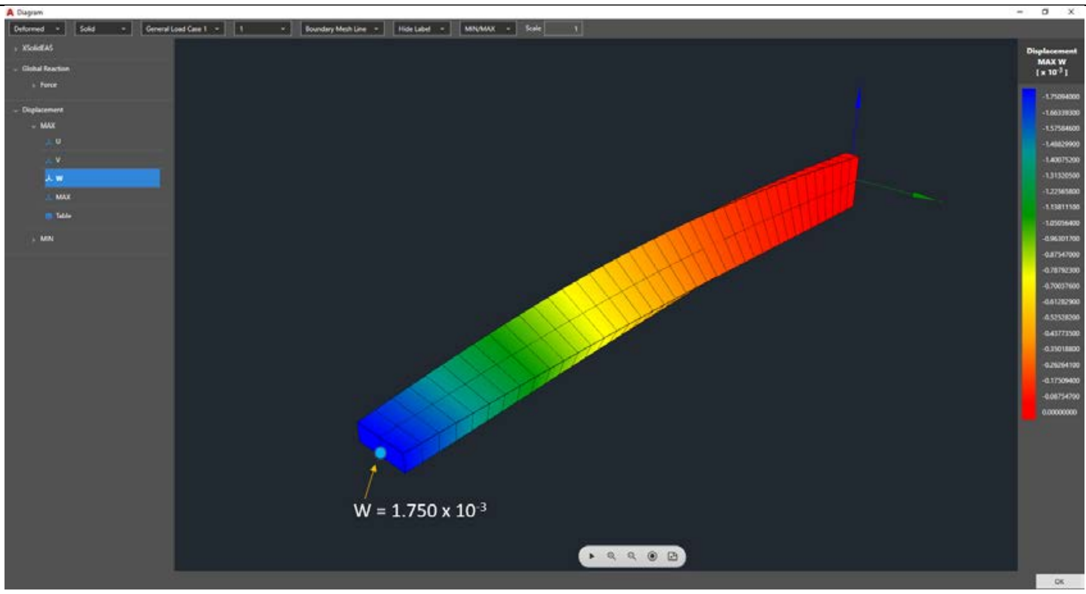


Fig. 4.6 Deformation Twist Beam with 0.32 thickness against out-plane unit load result Model

(c) For the case of thickness t = 0.0032, In-Plane Shear
Under Out-plane shear force at the free end, the analytic solution deflection of free end is 0.5256x104.

Table 4.3 Result of Twisted Beam with thickness = 0.0032 In-plane (V =0.5256 x 10^4)

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
2x2x1	$0.823\text{x}10^4$	0.157
4x2x1	$1.270\text{x}10^4$	0.242
8x2x1	$4.753\text{x}10^4$	0.904
12x2x1	$4.837\text{x}10^4$	0.920
40x2x1	$4.943\text{x}10^4$	0.941

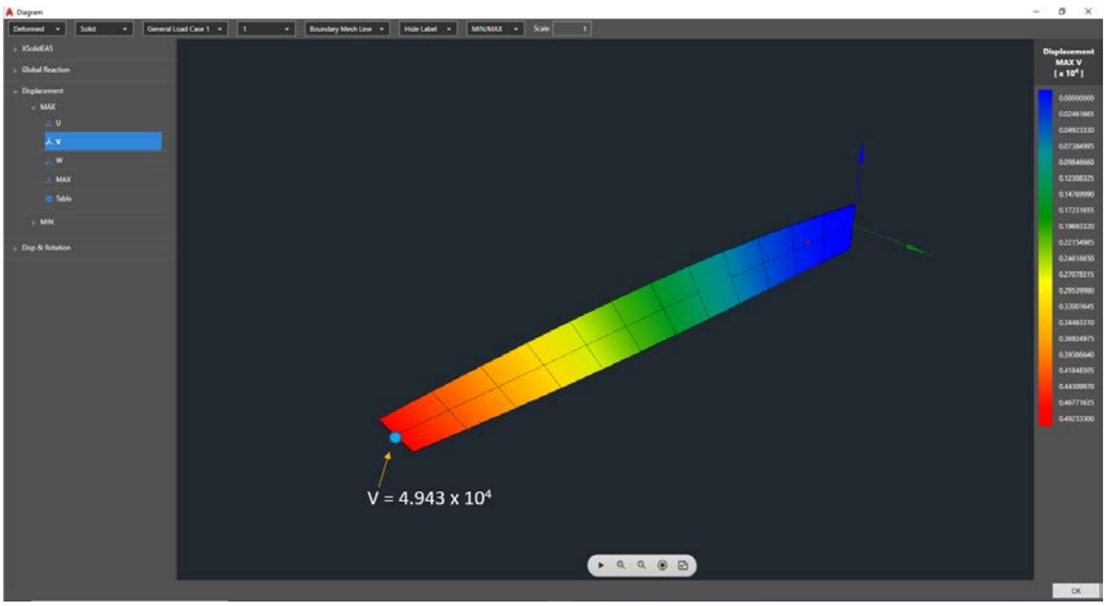


Fig. 4.7 Deformation Twist Beam with 0.0032 thickness against in-plane unit load result Model

(d) For the case of thickness t = 0.0032, Out-Plane shear

Under Out-plane shear force at the free end, the analytic solution deflection of free end is 0.1294x104.

Table 4.4 Result of Twisted Beam with thickness = 0.0032 Out-plane (V =0.1294 x 10^4)

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
2x2x1	$0.017x10^4$	0.139
4x2x1	$0.073x10^4$	0.565
8x2x1	$0.117x10^4$	0.902
12x2x1	$0.120x10^4$	0.925
40x2x1	$0.123x10^4$	0.951

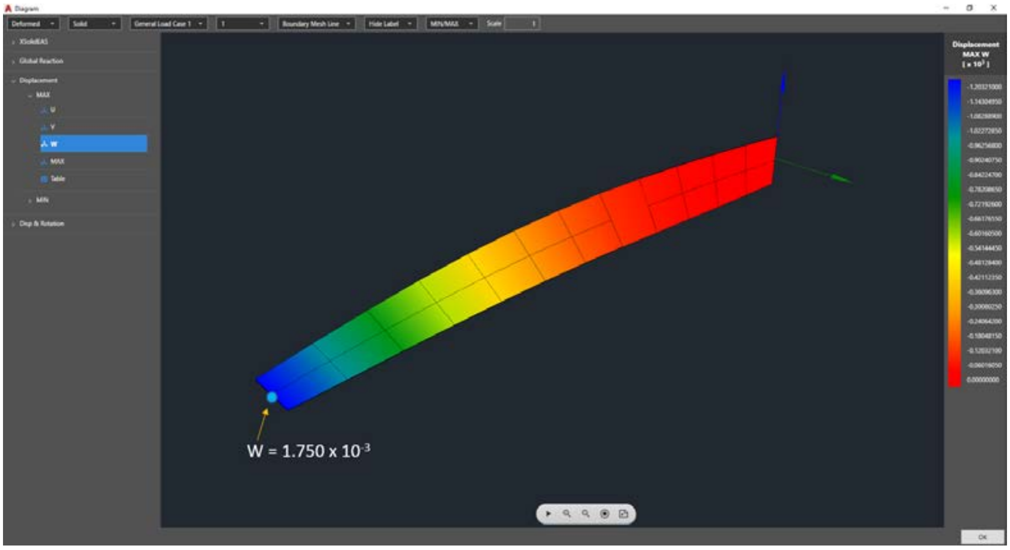


Fig. 4.8 Deformation Twist Beam with 0.0032 thickness against out-plane unit load result Model

Verification Example of X-SEA AutoCAD	No: Solid 005

Title: Bending Rhombic Plate

Problem Description

A simply supported rhombic plate in Figure 5.1 is subjected to a uniformly distributed load. This is a rather challenging test due to the singularity of its solution at the obtuse vertices.

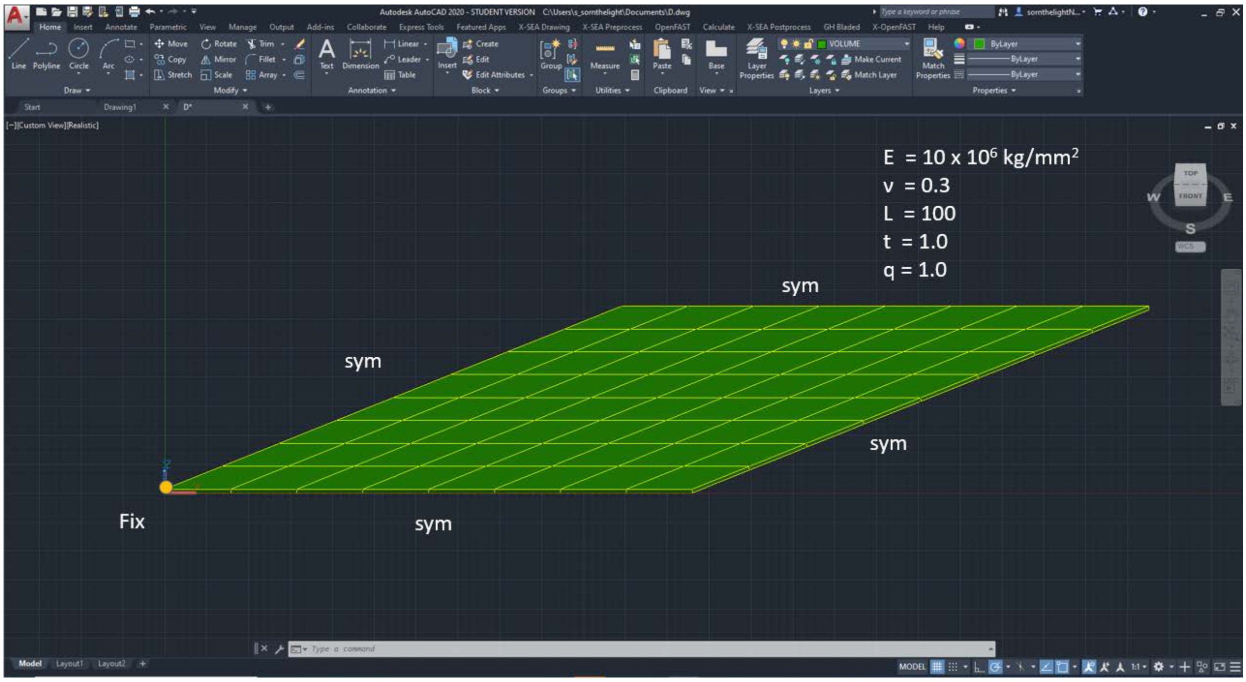


Fig.5.1 Rhombic Plate Model

Results

The numerical results of plate center is presented in Table 5.1 and figure 5.2 The reference solution is $W_c = 0.04455$

Table 5.1 Result of Bending Rhombic Plate Model (W = 0.04455)

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
4x4x1	0.04002	0.898
8x8x1	0.04228	0.949
16x16x1	0.04408	0.989
20x20x1	0.04451	0.999
32x32x1	0.04519	1.014

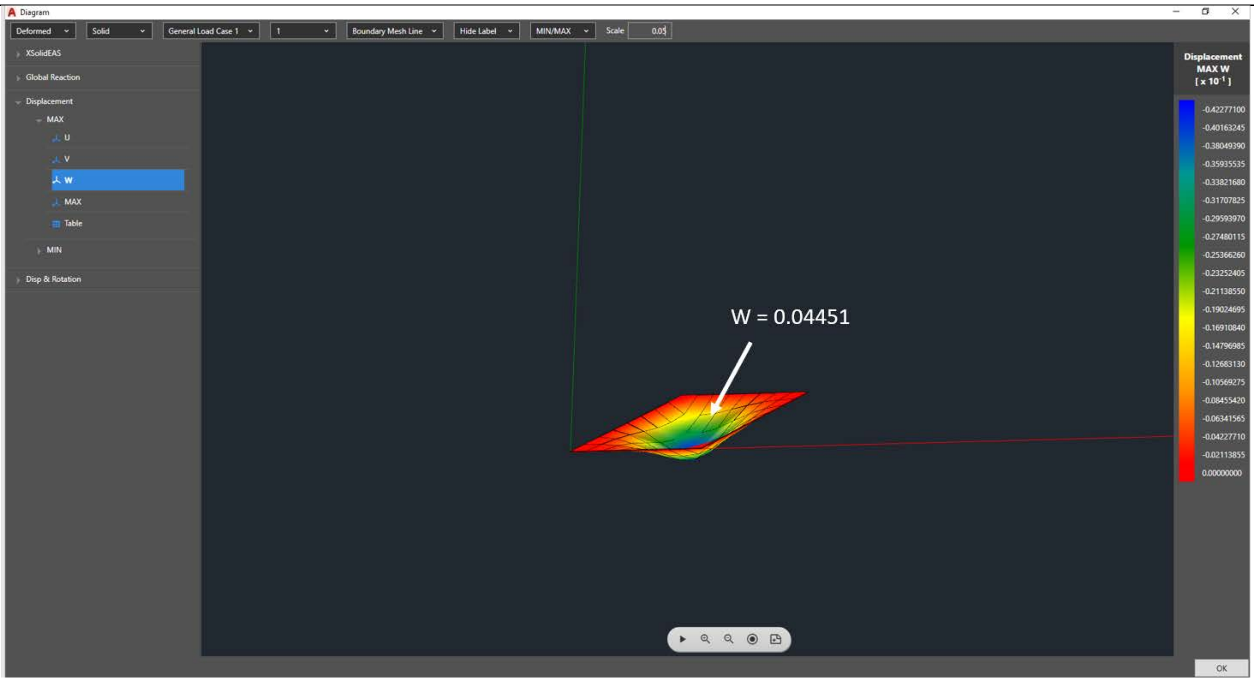


Fig.5.2 Deformation Bending Rhombic Plate result Model

	XFINASIT Co. LTD

Verification Example of X-SEA AutoCAD	No: Solid 006
Title: Bending of Rectangular Plate	
Problem Description	

The clamped rectangular plate problem under central point loading (Figure 6.1 and Figure 6.2) is applied to test shear locking by changing of aspect ratio. Teo aspect ratio of b/a =1 and 5 are considered.

(a) For the case of b/a = 1.0
The reference vertical deflection at the center of plate is 5.60 x 10^{-6}.

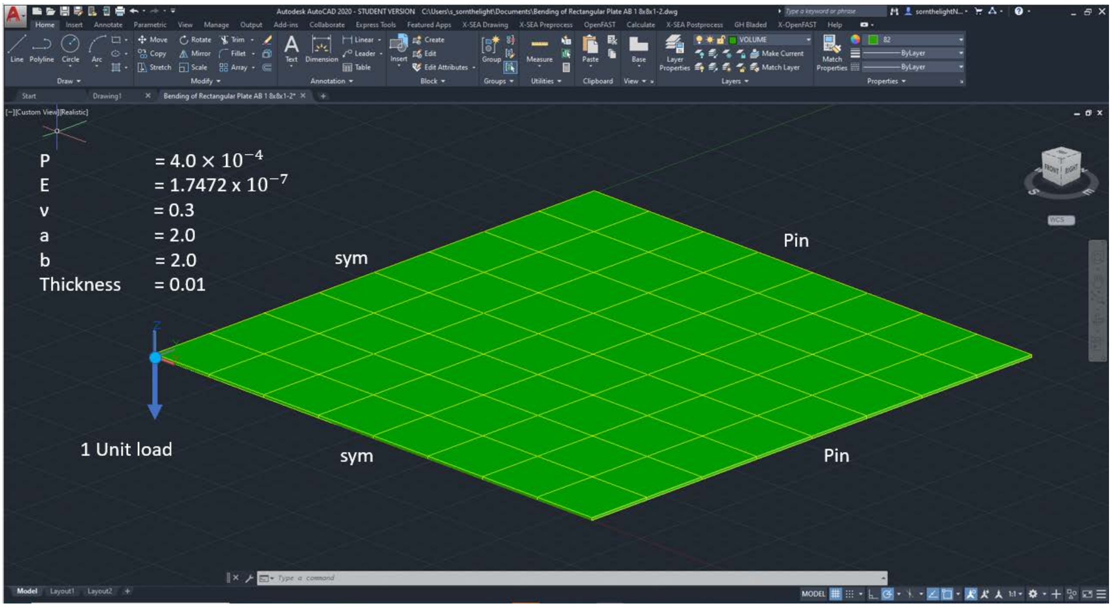


Fig. 6.1 Bending of Rectangular Plate (b/a = 1.0) Model

(b) For the case of b/a = 5.0
The reference vertical deflection at the center of plate is 7.23 x 10^{-6}.

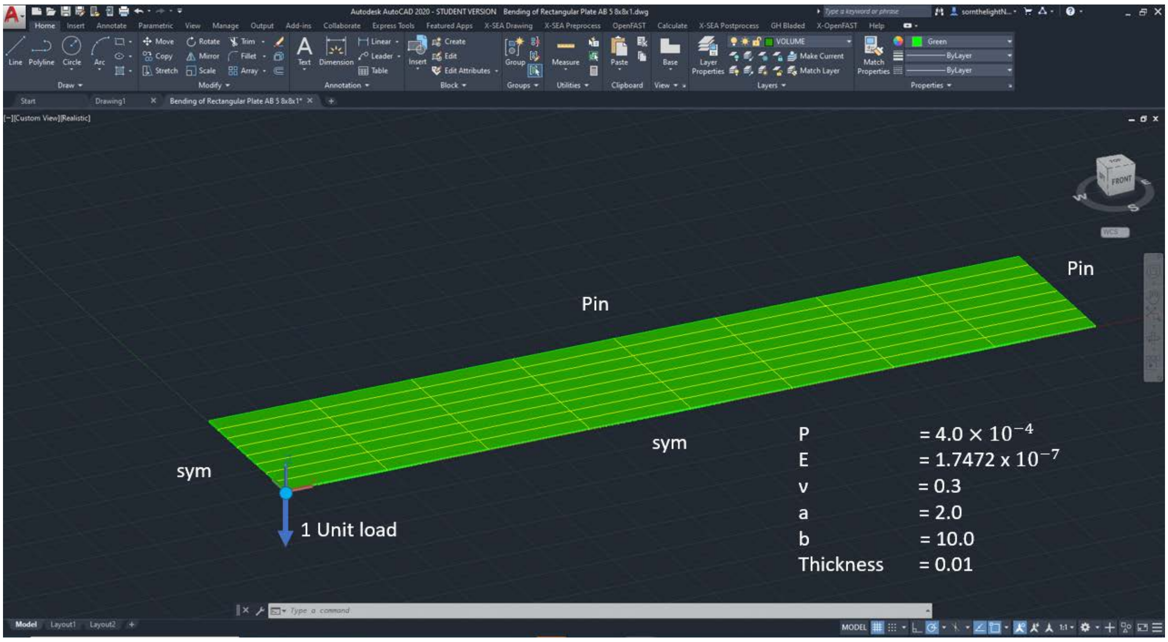


Fig. 6.2 Bending of Rectangular Plate (b/a = 5.0) Mode

Results

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
2x2x1	4.961×10^{-6}	0.886
4x4x1	5.448×10^{-6}	0.973
6x6x1	5.539×10^{-6}	0.989
8x8x1	5.571×10^{-6}	0.995

Table 6.1 Result of Bending of Rectangular Plate b/a = 1 (W = 5.60×10^{-6})

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
2x2x1	2.322×10^{-6}	0.321
4x4x1	6.146×10^{-6}	0.850
6x6x1	6.705×10^{-6}	0.927
8x8x1	6.921×10^{-6}	0.957
16x16x1	7.152×10^{-6}	0.989

Table 5.2 Result of Bending of Rectangular Plate b/a = 5 (W = 7.23×10^{-6})

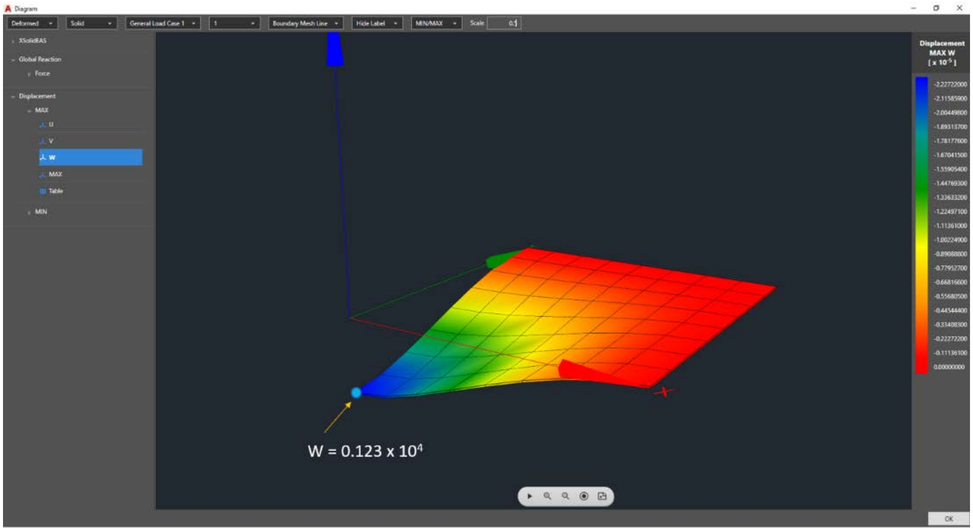


Fig.6.3 Deformation of Bending of Rectangular Plate (b/a = 1.0) Mode

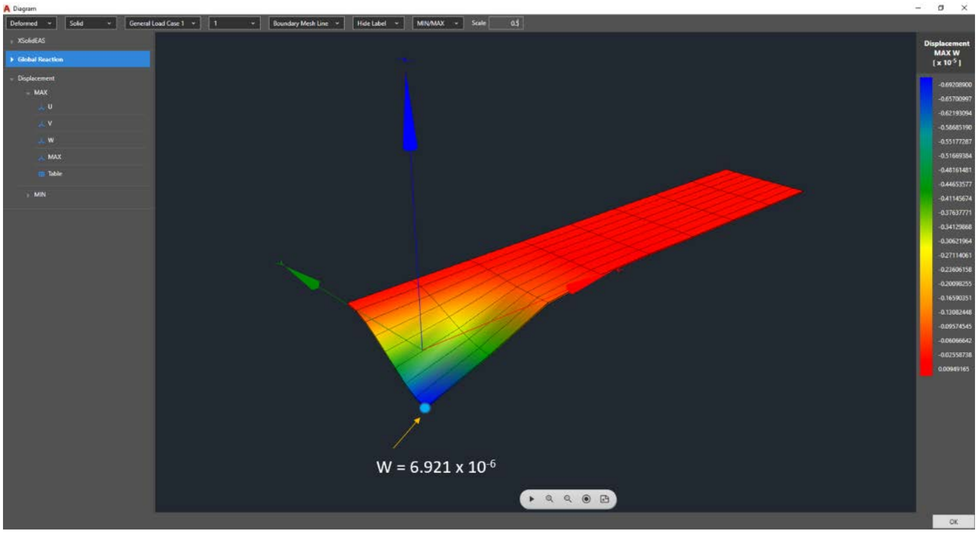


Fig. 6.4 Deformation of Bending of Rectangular Plate (b/a = 5.0)

Verification Example of X-SEA AutoCAD	No: Solid 007

Title: Scordellis-Lo Roof Problem

Problem Description

Both membrane and bending deformations are important to the solution of the Scordellis-Lo roof problem shown in figure 7. As the membrane deformation contributed significantly, this problem can be used to determine the element capability in modeling membrane state in curved shells.

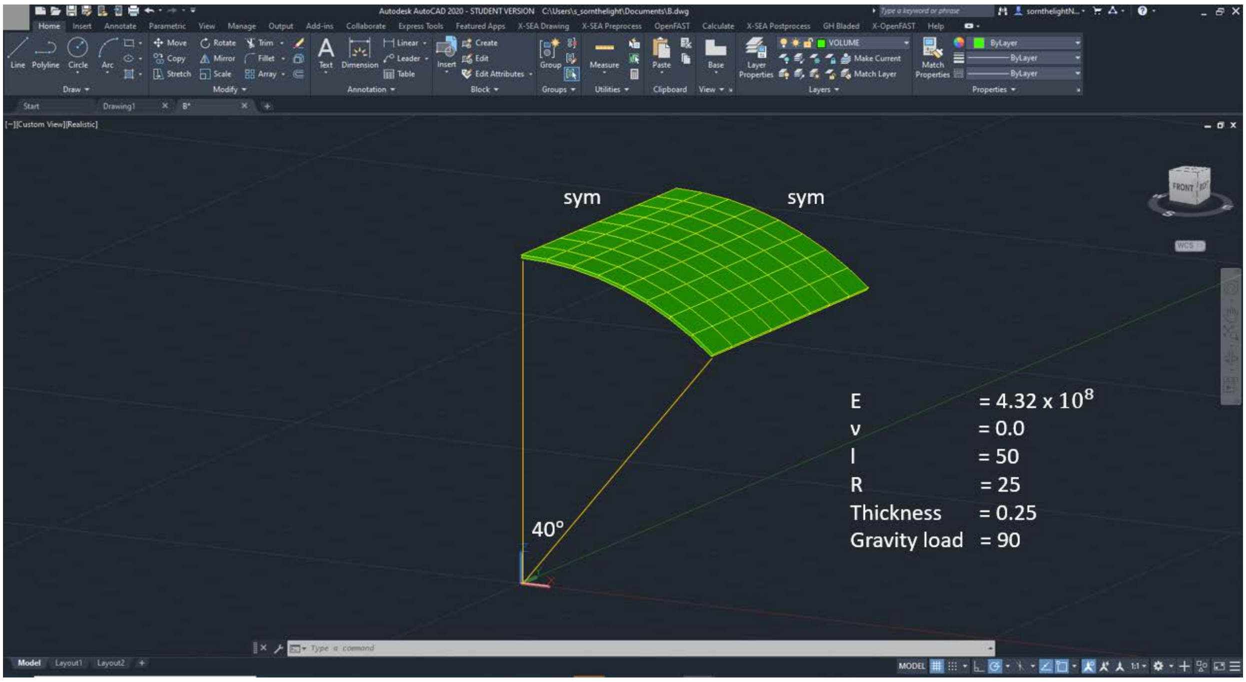


Fig. 7.1 Scordellis-Lo Roof Problem Model

Results

The reference solution of vertical deflection at point A is 0.3024.

Table 7.1 Result of Scordellis-Lo Roof Problem (W = 0.3024)

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
4x4x1	0.3224	1.066
6x6x1	0.3157	1.044
8x8x1	0.3154	1.043
16x16x1	0.3128	1.034

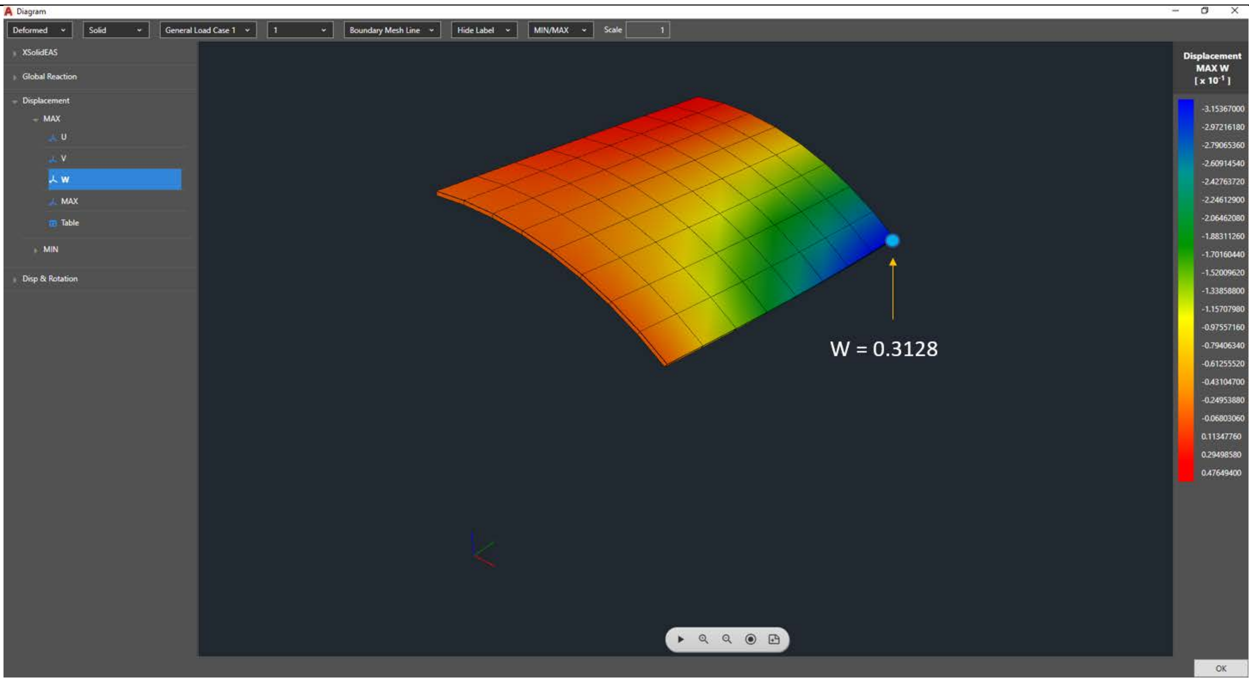


Fig. 7.2 Deformation of Scordellis-Lo Roof Model

Verification Example of X-SEA AutoCAD	No: Solid 008

Title: Pinched Cylinder with End Diaphragm

Problem Description

This problem is test for the element ability in modeling inextensional bending mode and complex membrane states. The vertical deflection is investigated.

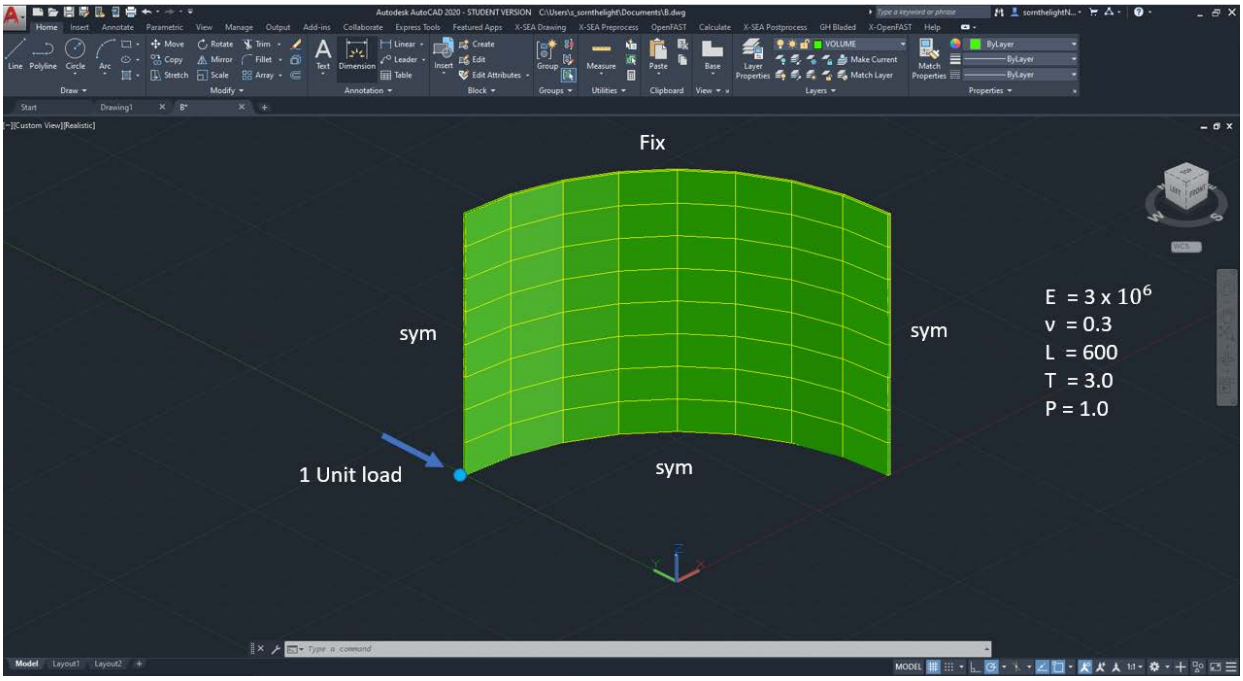


Fig. 8.1 Pinched Cylinder with End Diaphragm Model

Results

The reference value is $0.18248\text{x}10^{-4}$. Result with different meshes and elements are presented in table 7.1 and figure 7.2.

Table 8.1 Pined cylinder with End diaphragm Problem (W = $1.8248 \text{ x } 10^{-5}$)

Element size	Solution	Normalize Solution
	XSolid-8-EAS	XSolid-8-EAS
4x4x1	$1.953\text{x}10^{-5}$	0.107
8x8x1	$9.106\text{x}10^{-5}$	0.499
16x16x1	$1.662\text{x}10^{-5}$	0.911
32x32x1	$1.799\text{x}10^{-5}$	0.986

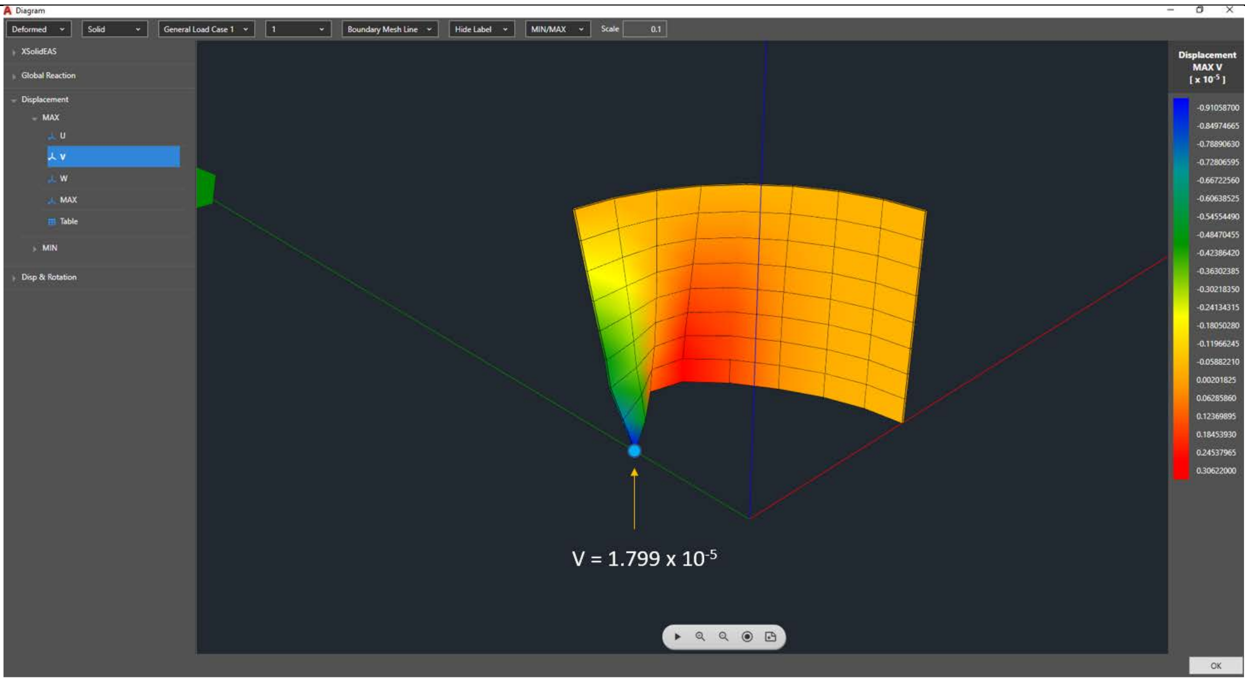


Fig. 8.2 Deflection of Pinched Cylinder with End Diaphragm Model

	XFINASIT Co. LTD

Verification Example of X-SEA AutoCAD	No: Solid 009

Title: Title: Geometrical nonlinear analysis of Clamped Plate Under Uniform Pressure

Problem Description

A geometrical nonlinear analysis of clamped plate shown in figure 9 is carried out. One quadrant is modeled due to the symmetry. The vertical deflection at the center is investigated by reference Timosehnko and Woinowsky.

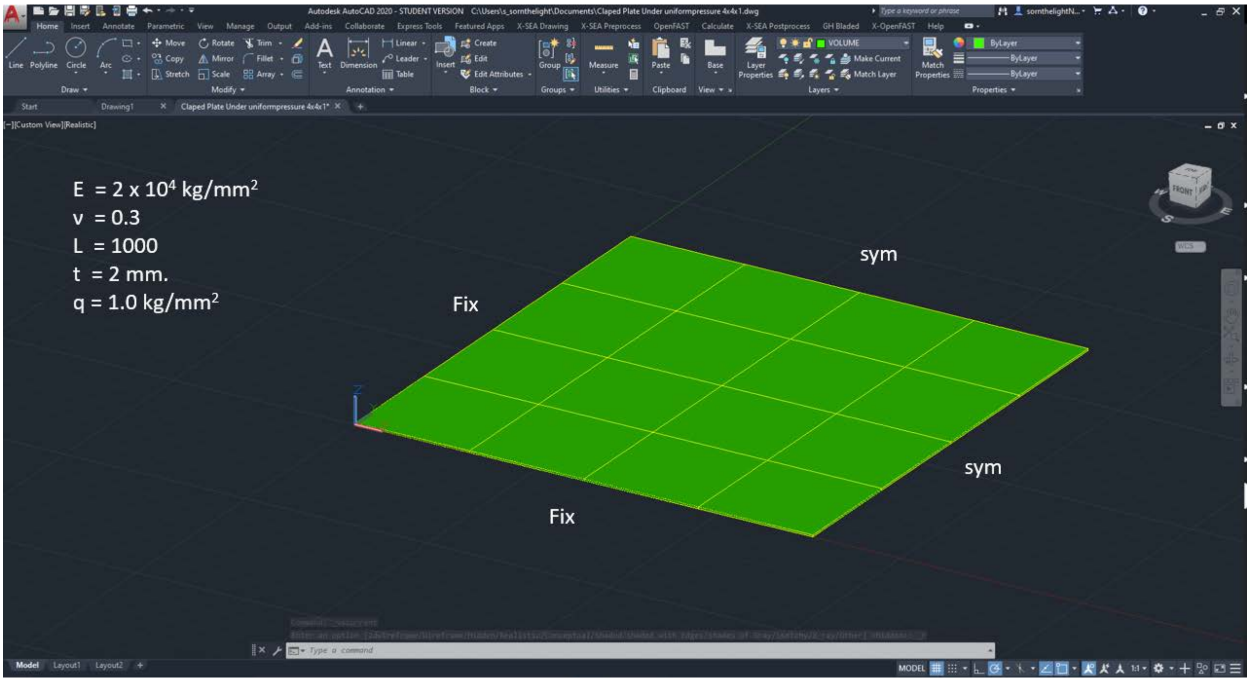


Fig.9.1 Clamped Plate Under Uniform Pressure Model

Results

Numerical results are taken out to list in table 9.1 as comparison to show the performance of present elements.

Table 9.1 Pressure load for different displacement (x 10^{-5})

Disp.	XSOLID-8-EAS
0.5	0.609
1.0	1.333
1.5	2.289
2.0	3.603
2.2	4.259
2.4	5.002
2.6	5.842
2.8	6.787
3.0	7.848

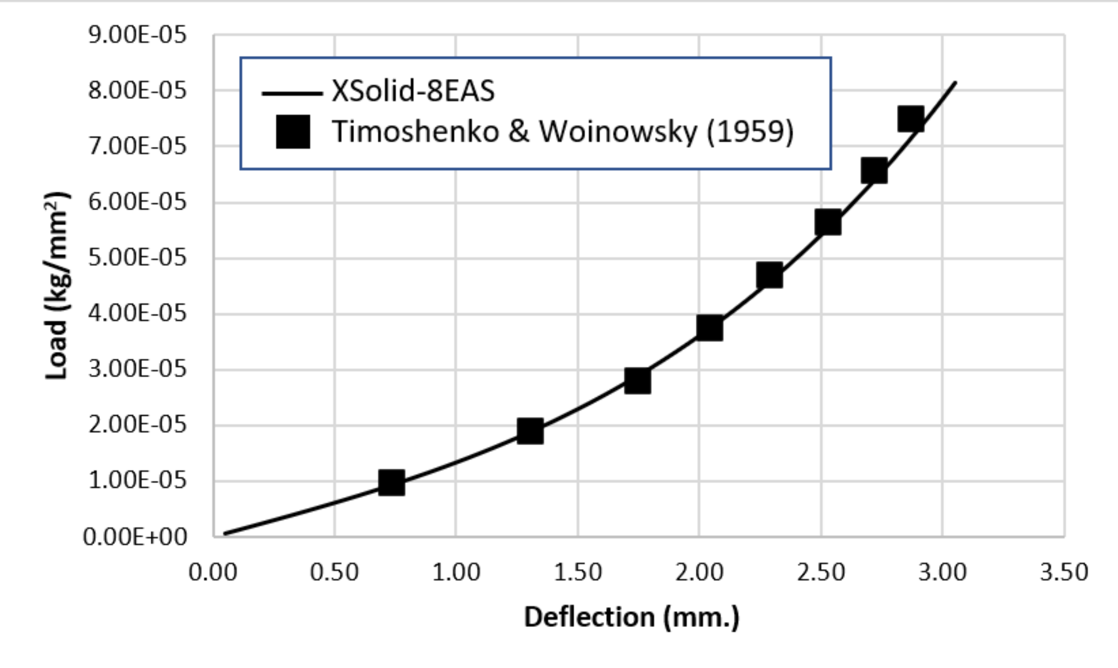


Fig.9.2 Load-deflection curve of clamped plate (at center)

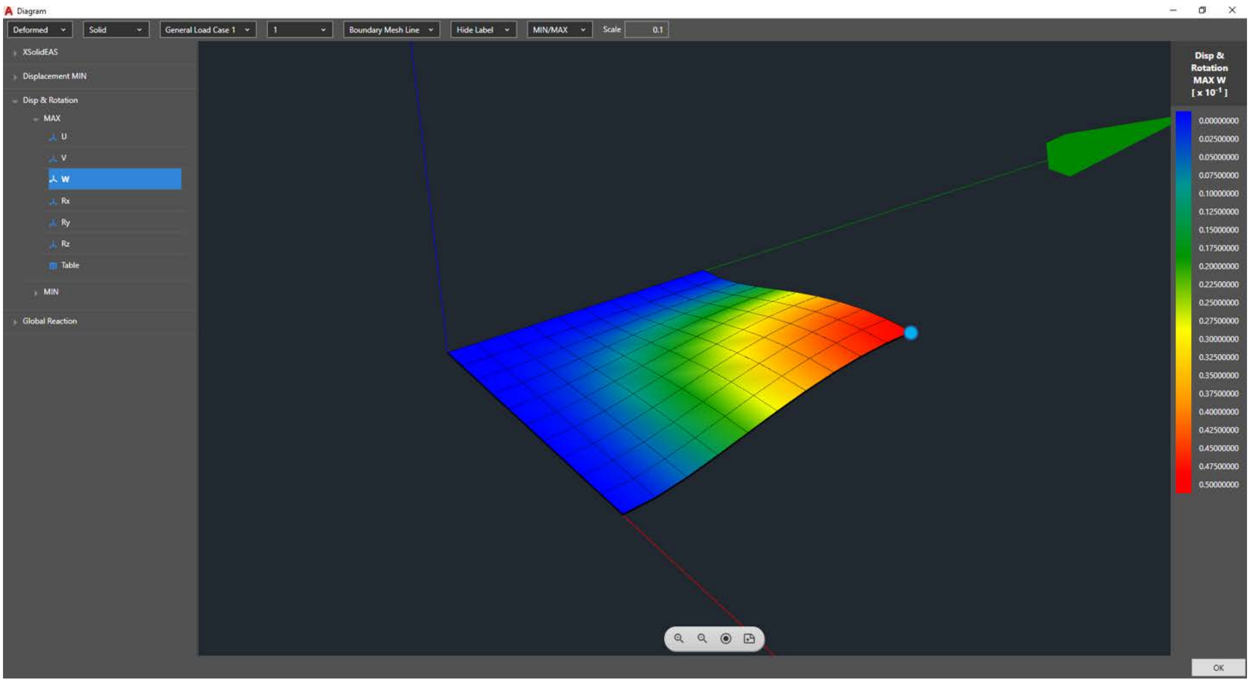


Fig.9.3 Deformation Clamped Plate Under Uniform Pressure Model

XFINASIT Co. LTD

Verification Example of X-SEA AutoCAD	No: Solid 010
Title: Geometrical nonlinear analysis of Hinged Cylindrical Shell	

Problem Description

A geometrical nonlinear analysis of hinged shell is carried out. The cylindrical shell is hinged at the straight edges and free at the curved edges. One quadrant of the shell is modeled. The mesh size is 10*10*4. The geometry and the material are shown in Figure 10.1

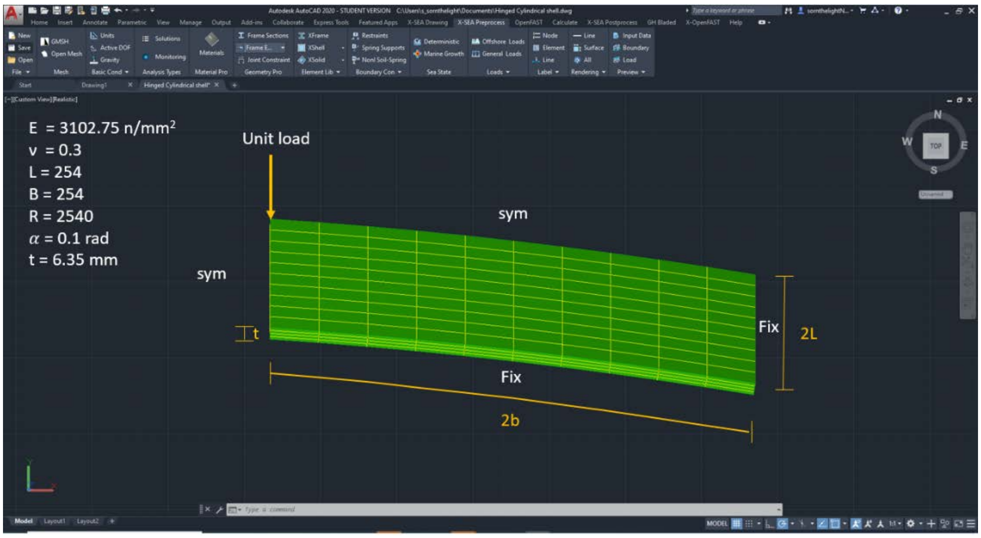


Fig.10.1 Hinged Cylindrical Shell Model

Results

The result obtained form present solid element X-Solid-8-EAS is plotted. The deflection of point A is investigated. The results obtained are plotted in figure 10.2

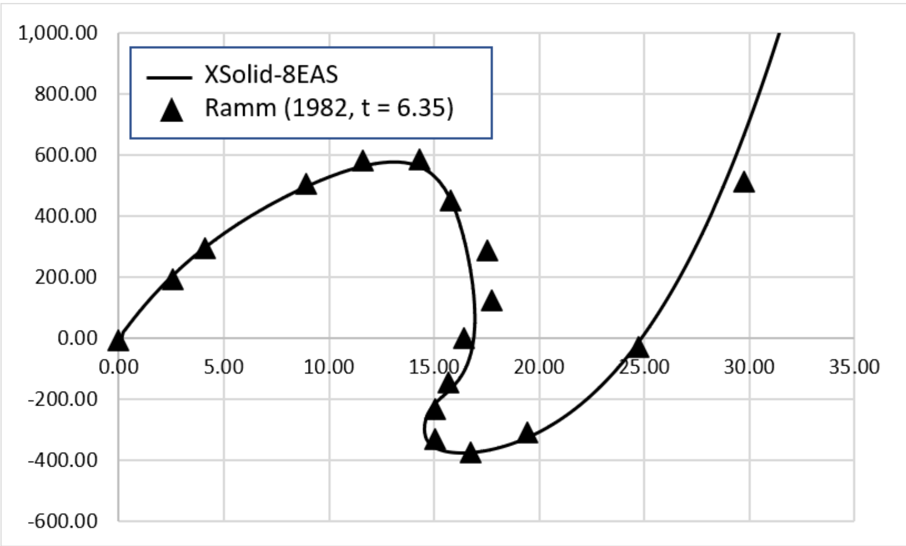


Fig.10.2 Load-deflection curve of hinged cylindrical shell (t = 6.35) at loaded point

	XFINASIT Co. LTD