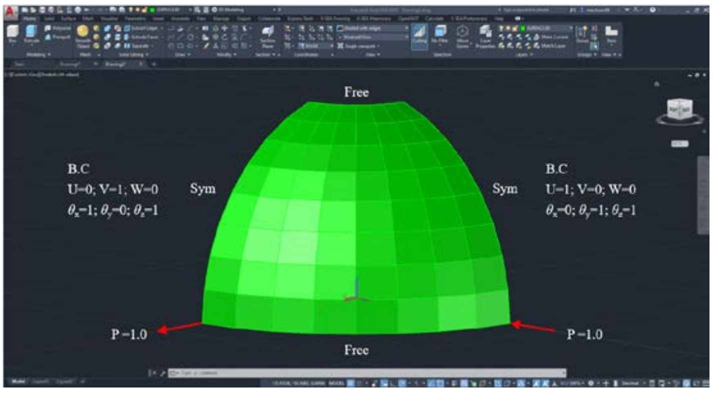
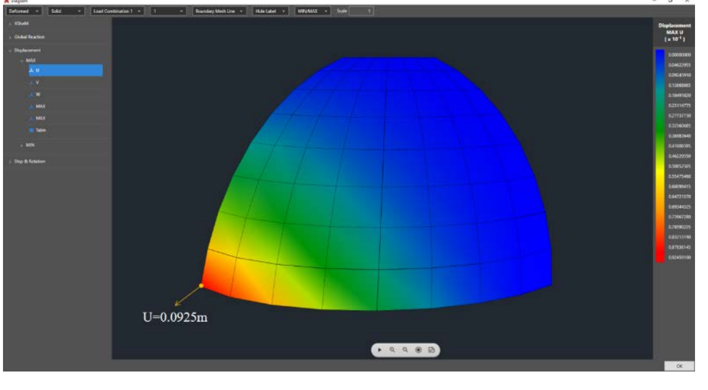
Verification report: Xshell 2021-09-18

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

"X-SEA AutoCAD"

Verification of 3 & 4-node Shell element (XShell)





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Verification Example of X-SEA AutoCAD	No: Shell Element 001
Title: Hemispherical Shell	
Problem Description	

Two geometries have been used for this problem; one is a full hemispherical shell (Fig.1.2) and another is a hemispherical shell with an 18° hole (Fig.1.1). Both shells have the same radius, thickness, material properties and loading conditions.

Radius = 10; t = 0.04; E = 6.825×10^7; ν=0.3.

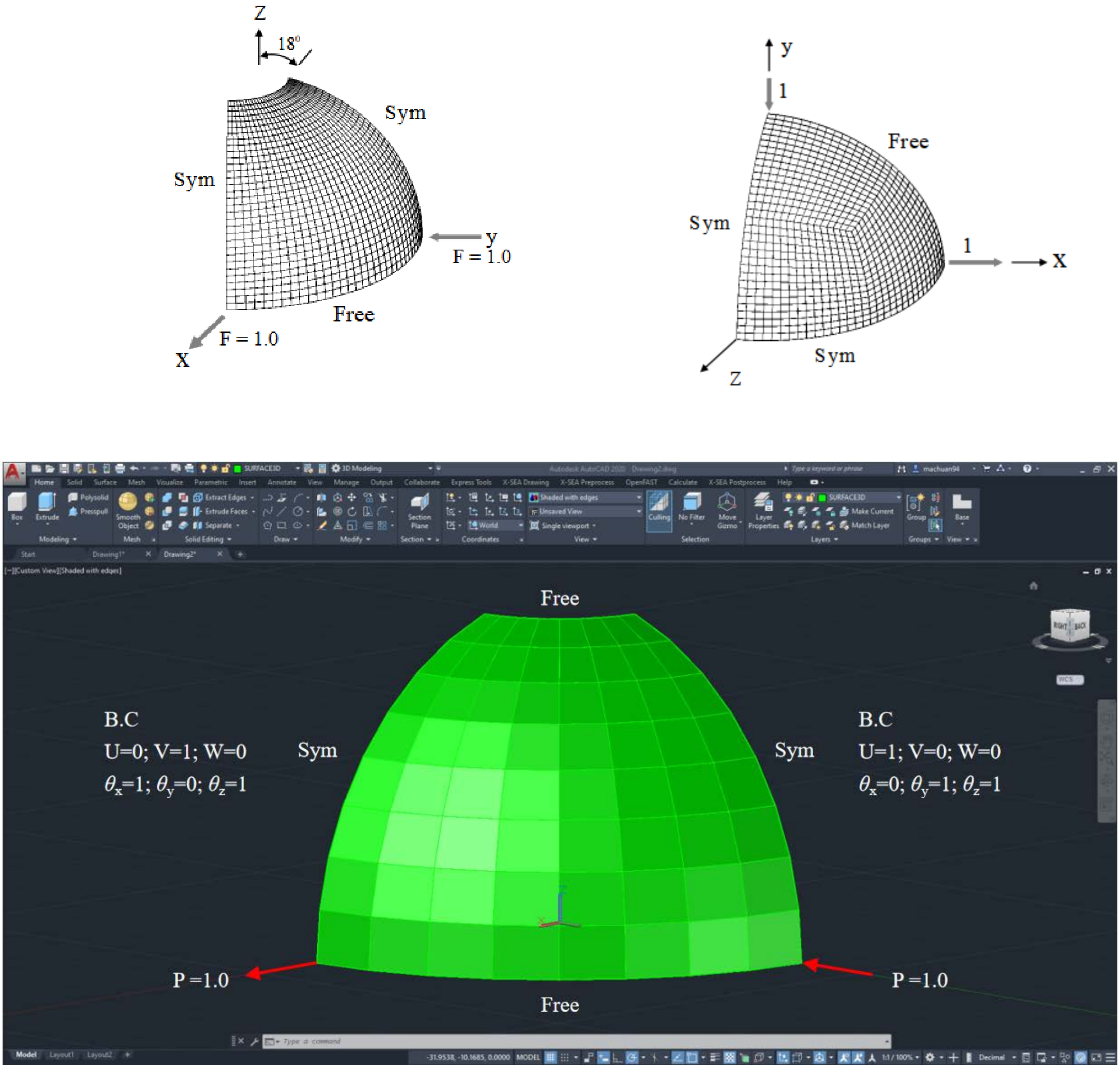


Fig. 1.1 Hemispherical shell model with 18° hole and properties (8×8, 4 ANS)

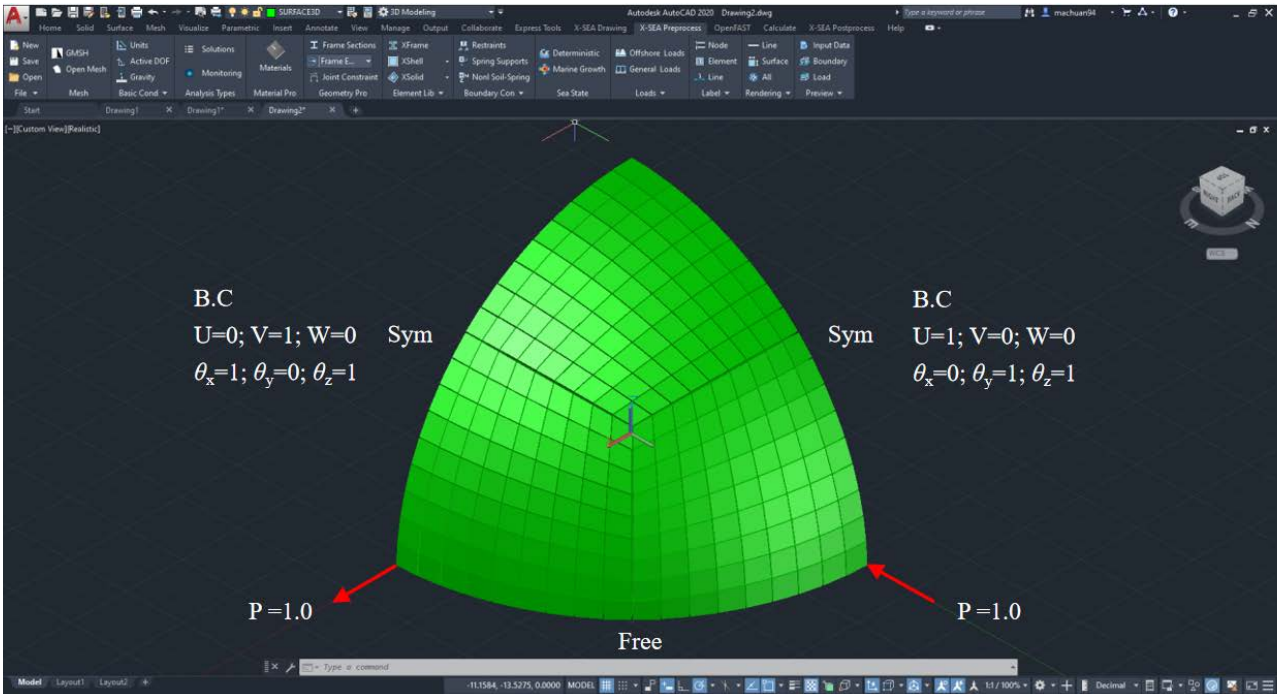


Fig. 1.2 Full hemispherical shell model and properties (18×18, 4 ANS)

Results

Table 1.1 Normalized solutions of hemispherical shell with 18° hole (Reference=0.093)

Elements Per side	Simo, et al.	QUAD4	XSHELL-4-ANS
2	0.919	0.972	0.583 (0.0542)
4	1.004	1.024	0.943 (0.0869)
8	0.998	1.005	0.995 (0.0925)
16	0.999	-	1.001 (0.0931)

Table 1.2 Normalized solutions of hemispherical shell with 18° (Reference=0.093)

Nodes Per side	Mesh A		Mesh B	
	NLT	XSHELL-3QSI	NLT	XSHELL-3QSI
3	0.038	0.4156 (0.0384)	0.038	0.413 (0.0384)
5	0.044	0.1331 (0.0123)	0.044	0.141 (0.0131)
9	0.325	0.3431 (0.0317)	0.326	0.348 (0.0324)
17	0.862	0.8690 (0.0803)	0.864	0.868 (0.0807)
21	0.933	0.9978 (0.0922)	0.934	0.941 (0.0875)
33	0.933	0.9989 (0.0923)	0.934	0.994 (0.0924)

Table 1.3 Normalized solutions of full hemispherical shell (Reference=0.0924)

Elements Per side	Simo, et al.	MITC4	QPH	S4R5	XSHELL-4-ANS
2	-	-	-	1.025	0.091 (0.008444)
4	0.651	0.39	0.28	1.031	0.423 (0.039070)
8	0.968	0.91	0.86	0.989	0.908 (0.083936)
12	-	-	-	-	0.951 (0.087909)
16	-	-	-	-	0.958 (0.088484)

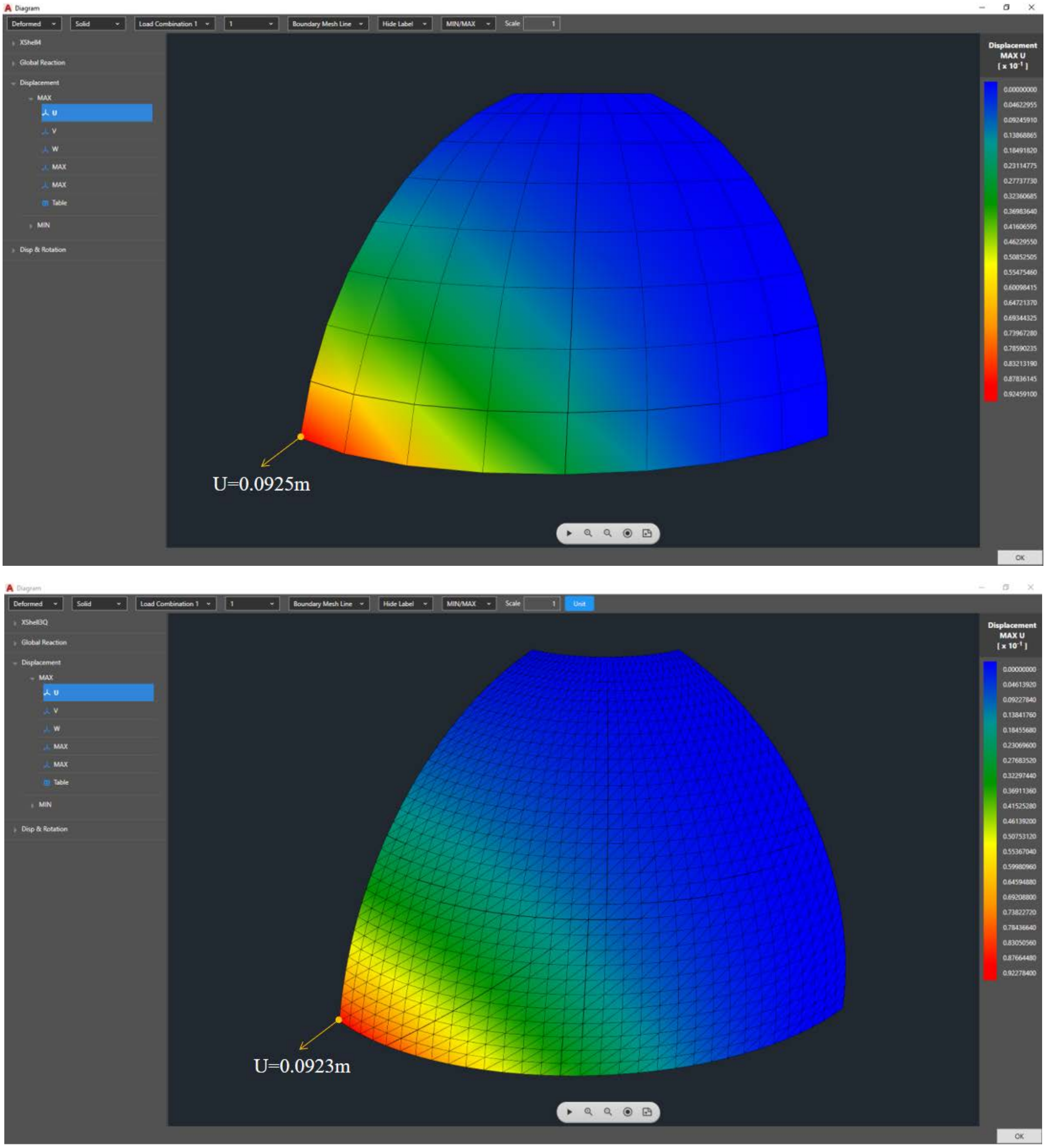
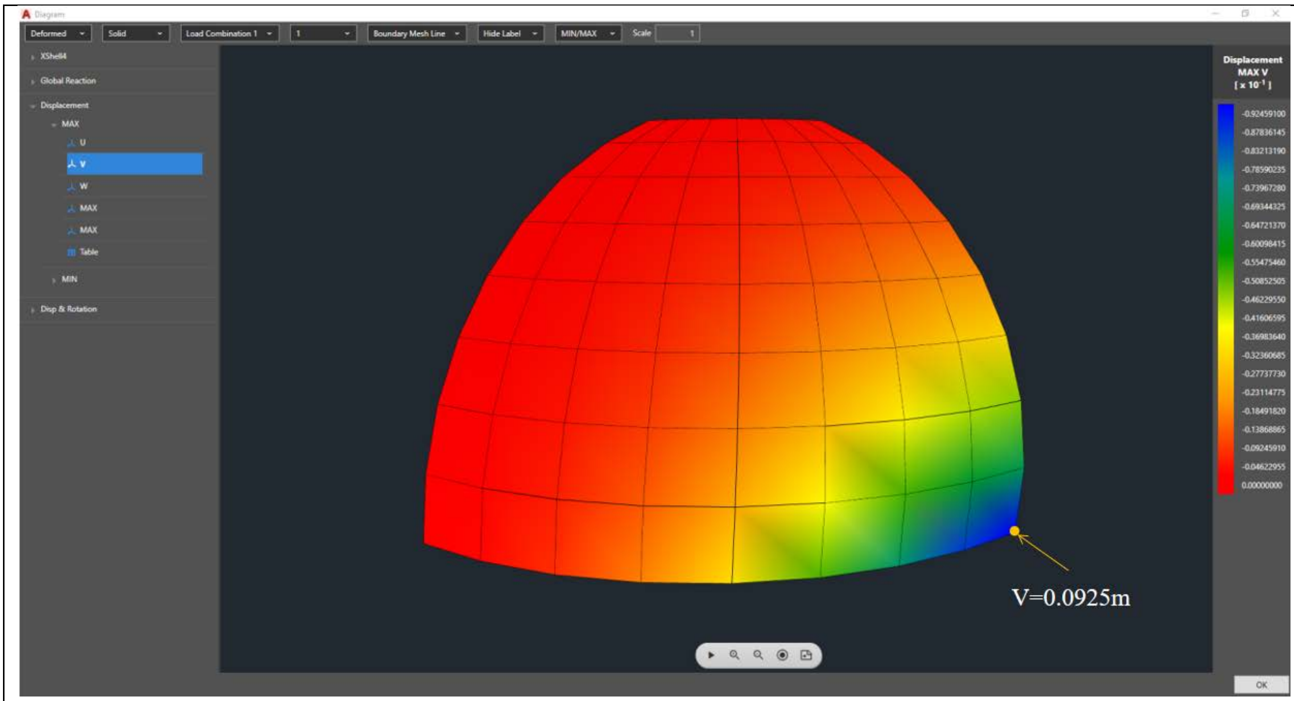


Fig.1.3 Deformation of hemispherical shell model with 18° hole-U (8×8, 4 ANS & 32×32, 3QSI)



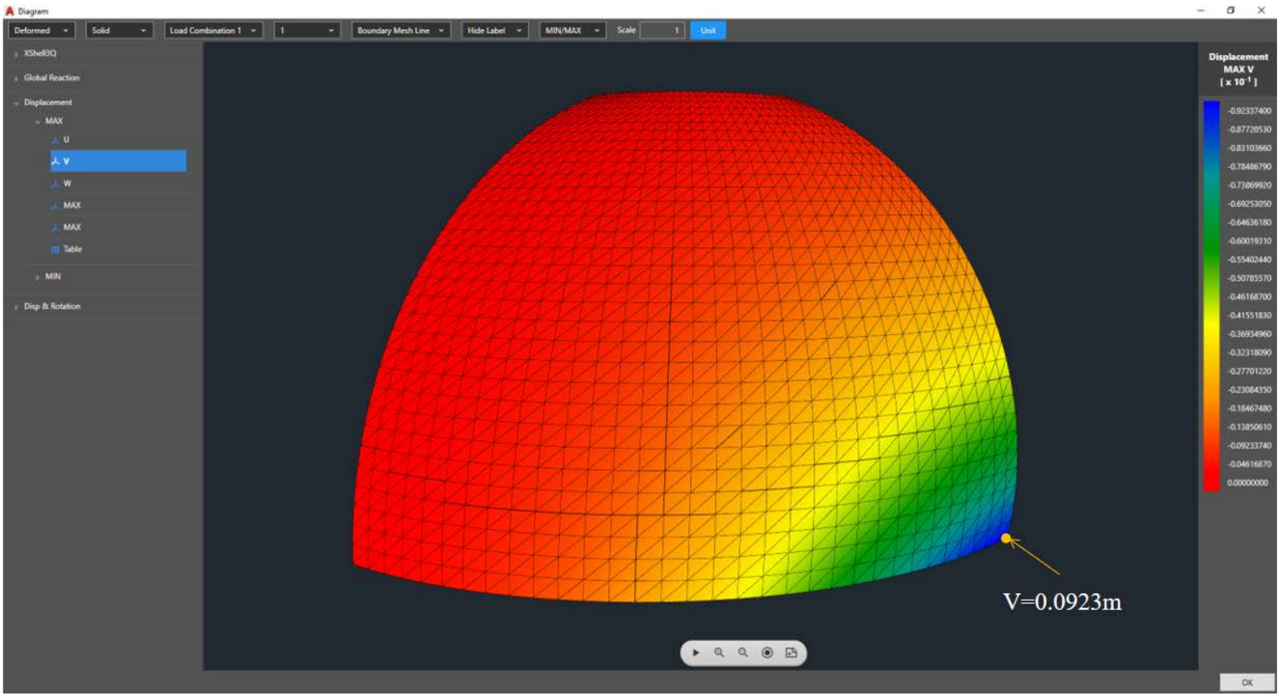


Fig.1.4 Deformation of hemispherical shell model with 18° hole-V (8×8, 4 ANS & 32×32, 3QSI)

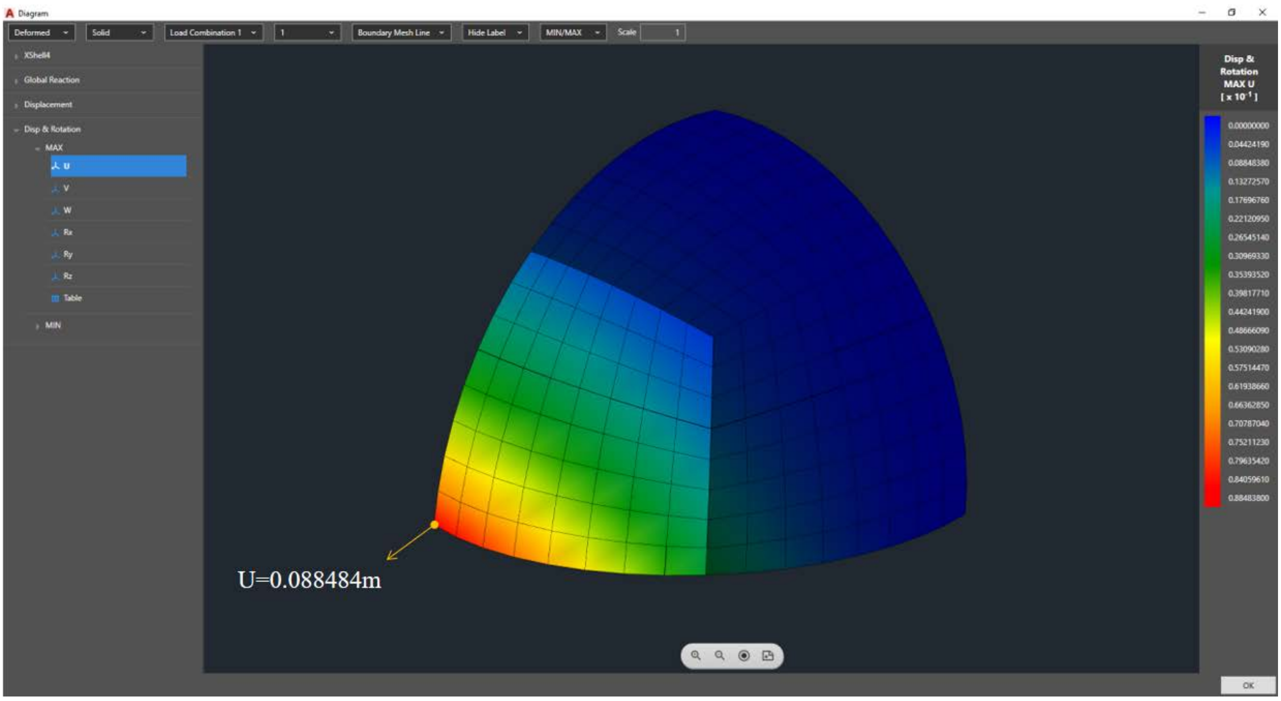


Fig.1.5 Deformation of full hemispherical shell model-U (18×18, 4 ANS)

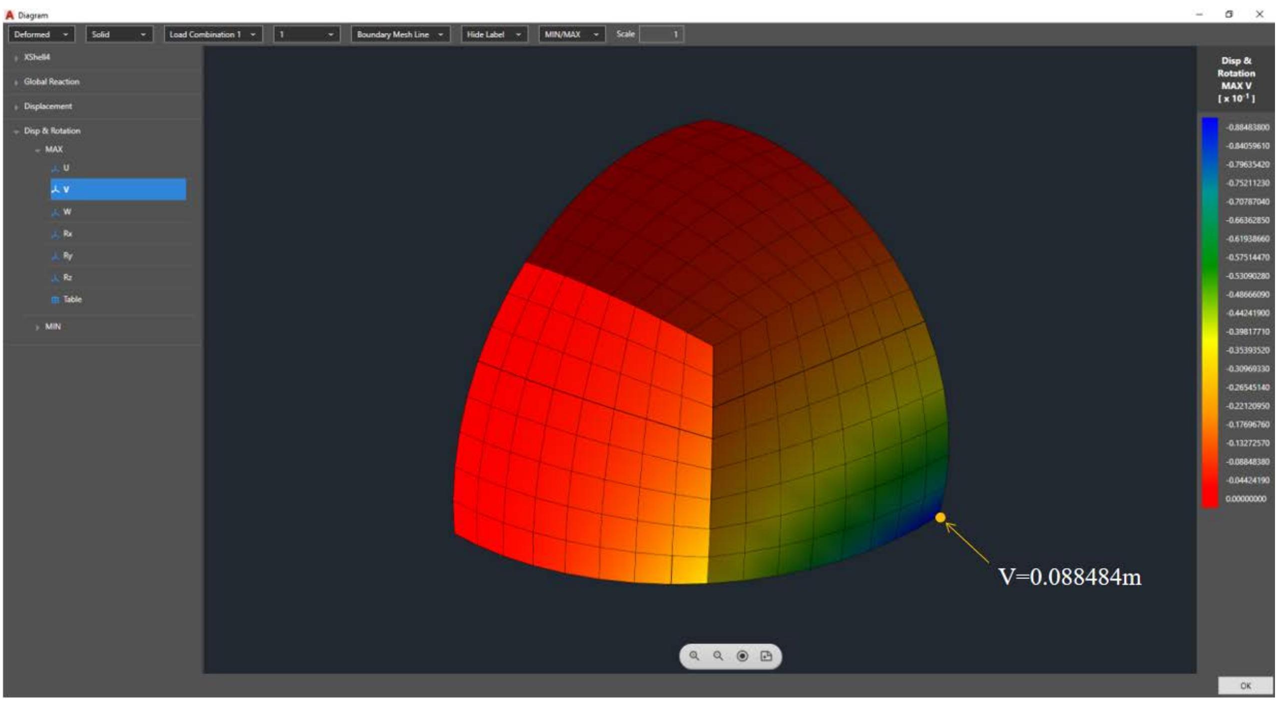


Fig.1.6 Deformation of full hemispherical shell model-V (18×18, 4 ANS)

Verification Example of X-SEA AutoCAD	No: Shell Element 002

Title: Scordelis-Lo Roof

Problem Description

The Scordelis-Lo roof is a short cylinder section supported by rigid diaphragms at the edges. Taking advantage of symmetry, only one quarter was used in the analysis of the problem. With only a 10x10 mesh, good convergence to the reference solution was obtained. The reference solution is 0.3024.

Radius=25; Length=50; t=0.25; E=4.32x10^8; ν=0; Load=90 per unit area (-) dir.

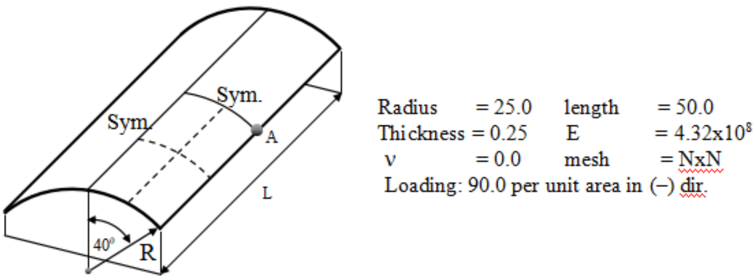


Figure 2.3 (a) Scordelis-Lo Roof Model and Properties

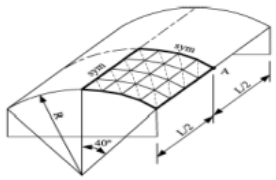


Figure 2.3 (b) Scordelis-Lo Roof Mesh A

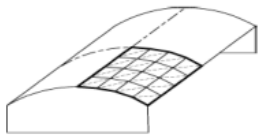


Figure 2.3(c) Scordelis-Lo Roof Mesh B

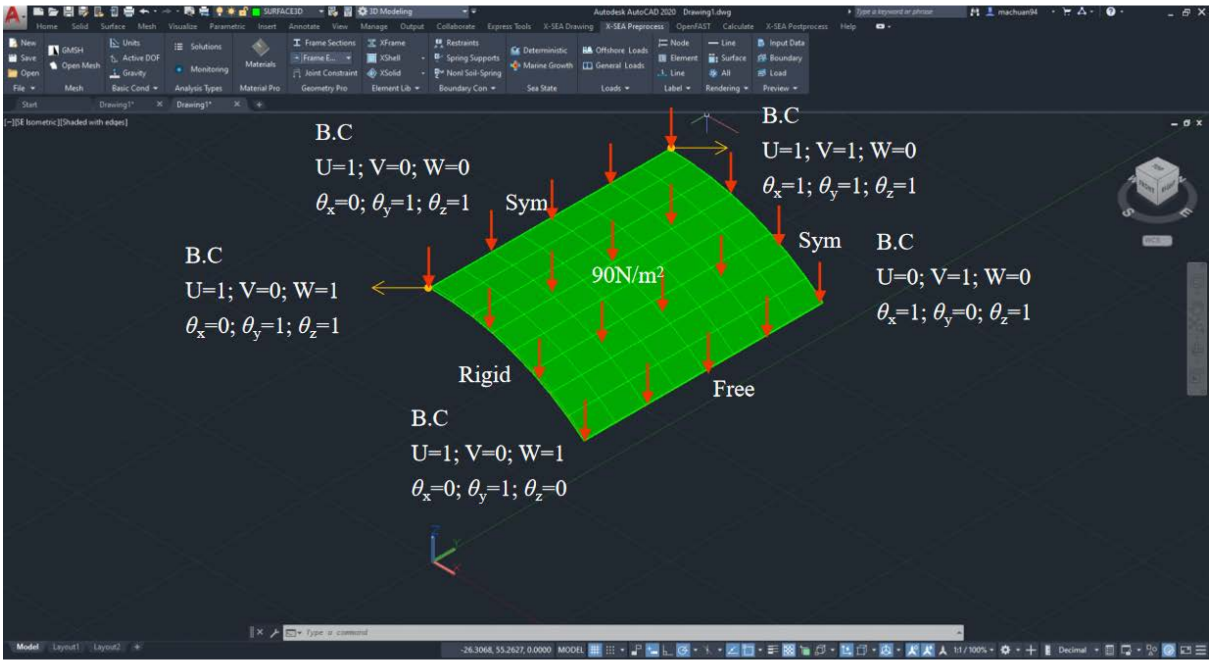


Fig. 2.1 Scordelis-Lo Roof model and properties-1/4 Sym model (8×8, 4 ANS)

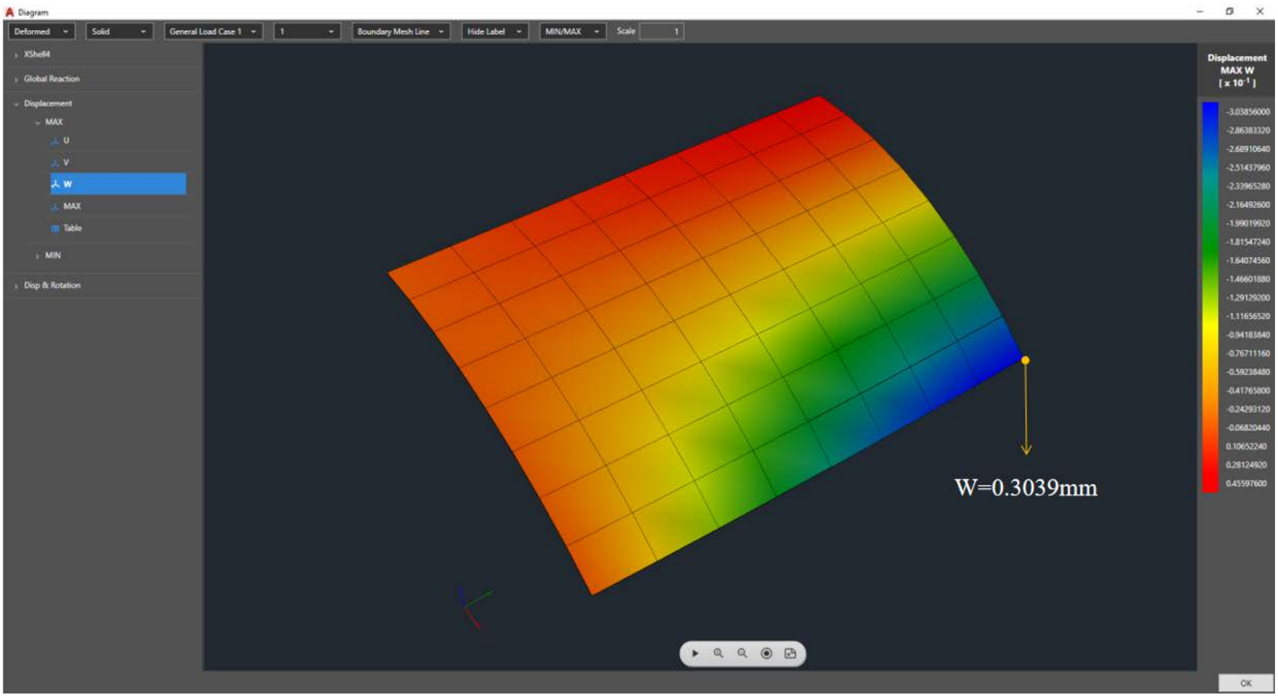
Results

Table.2.1 Normalized results of Scordelis-Lo Roof-4 ANS (Reference=0.3024)

Mesh	MITC4	Simo, et al.	XSHELL-4-ANS 1/4 Sym model
2x2	-	-	1.3740 (0.4155)
4x4	0.94	1.083	1.0446 (0.3159)
6x6	-	-	1.0136 (0.3065)
8x8	0.97	1.015	1.0050 (0.3039)
10x10	-	-	1.0011 (0.3027)
16x16	1.00	1.000	0.9974 (0.3016)

Table.2.2 Normalized results of Scordelis-Lo Roof-3 QSI (Reference=0.3024)

Nodes Per side	Mesh A		Mesh B	
	NLT	XSHELL-3QSI	NLT	XSHELL-3QSI
3	1.005	0.9775 (0.2956)	1.334	1.3462 (0.4071)
5	0.916	0.9160 (0.2770)	0.985	0.9937 (0.3005)
9	0.967	0.9663 (0.2922)	0.983	0.9851 (0.2979)
17	0.987	0.9864 (0.2983)	0.991	0.9911 (0.2997)
21	0.990	0.9891 (0.2991)	0.993	0.9921 (0.3000)



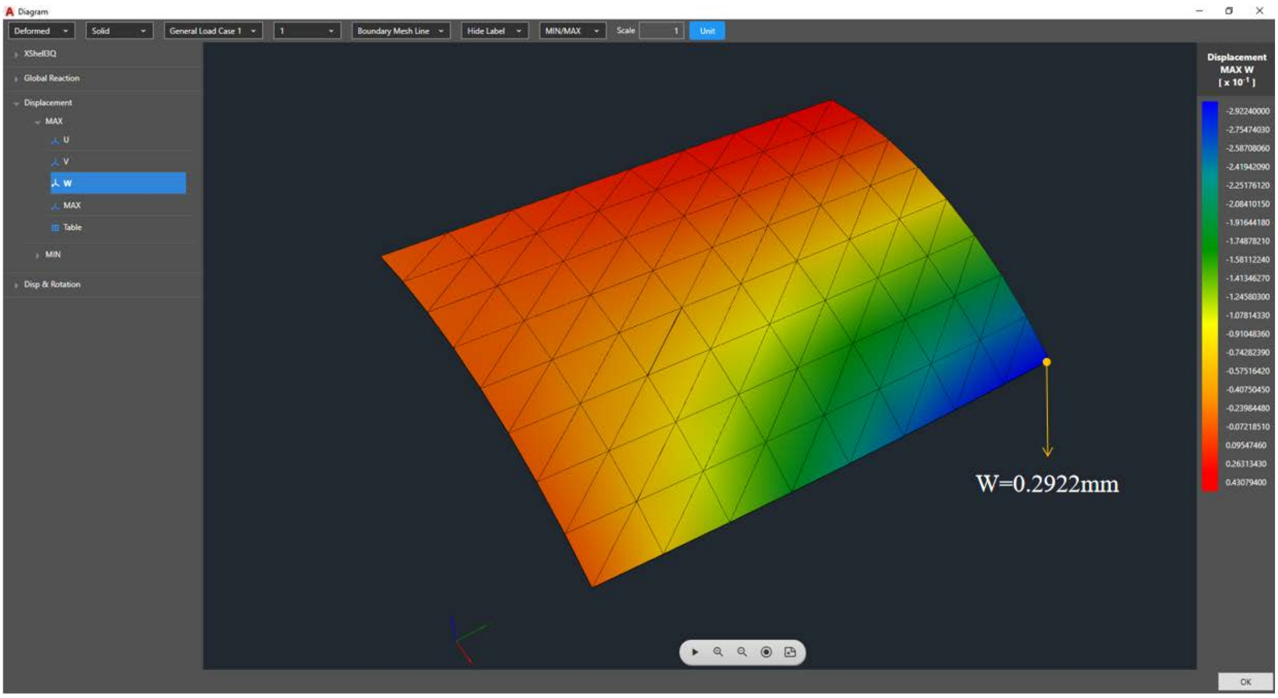


Fig.2.2 Deformation of Scordelis-Lo Roof model-1/4 Sym model (8×8, 4ANS & 8×8, 3QSI)

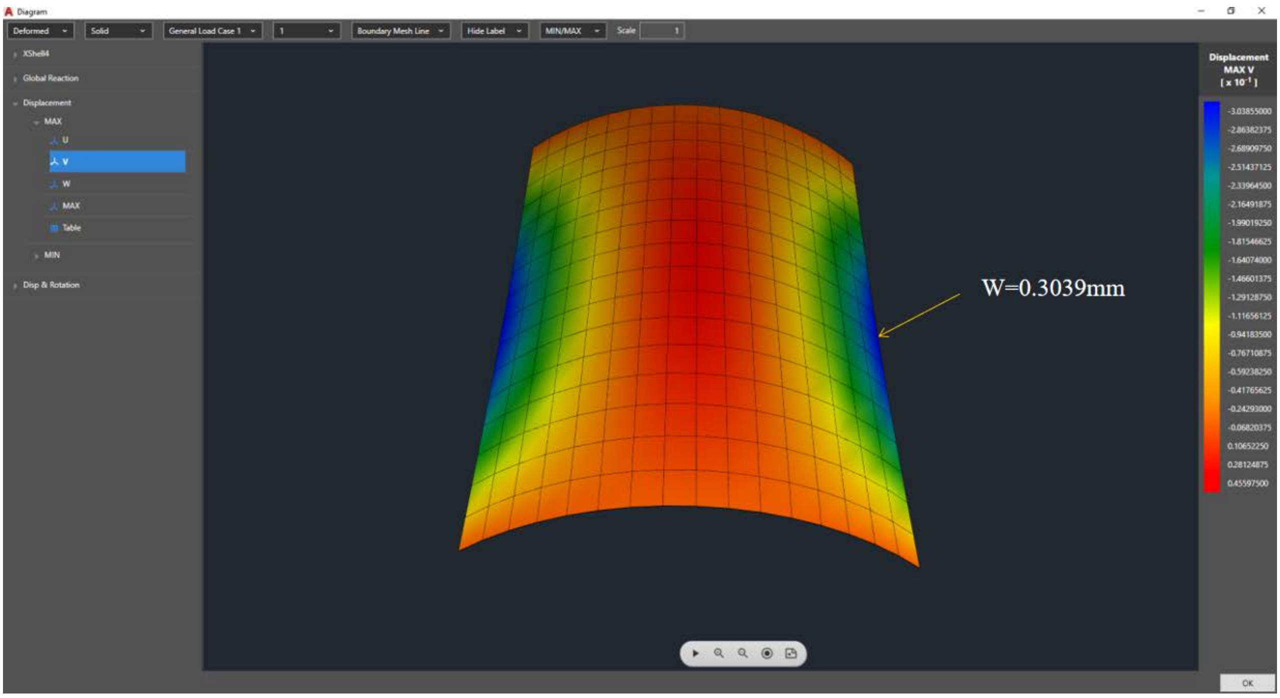


Fig.2.3 Deformation of Scordelis-Lo Roof model-Whole model (16×16 elements, 4 ANS)

Verification Example of X-SEA AutoCAD	No: Shell Element 003

Title: Pinched Cylinder

Problem Description

A short cylinder with rigid end diaphragms subjected to two pinching forces was analyzed. The radial displacement at the location of the point load is 0.18248e-4. Very good results were obtained using the present elements when compared with the references as shown in table 3.1 and 3.2.

Radius=300; t=3.0; E=3x10^6; v=0.3; Length=600; Load P=1.0.

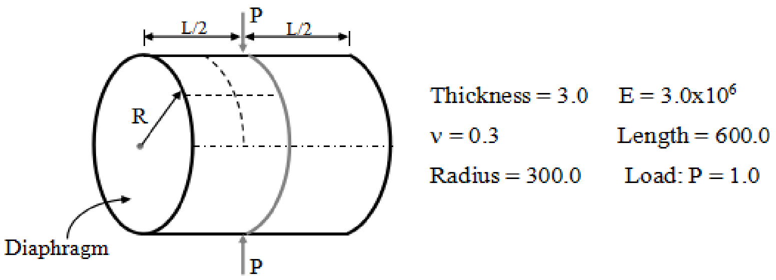


Figure 2.4 (a) Pinched Cylinder and Properties

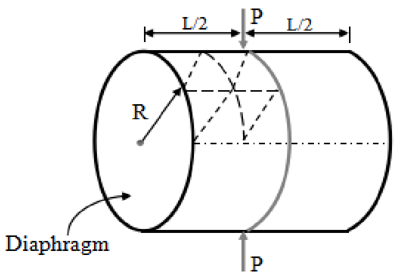


Figure 2.4 (b) Pinched Cylinder Mesh A

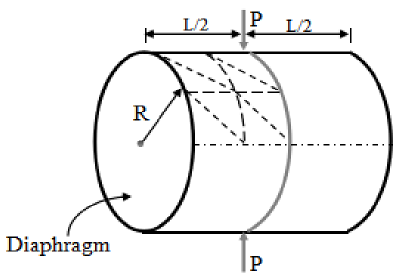


Figure 2.4(c) Pinched Cylinder Mesh B

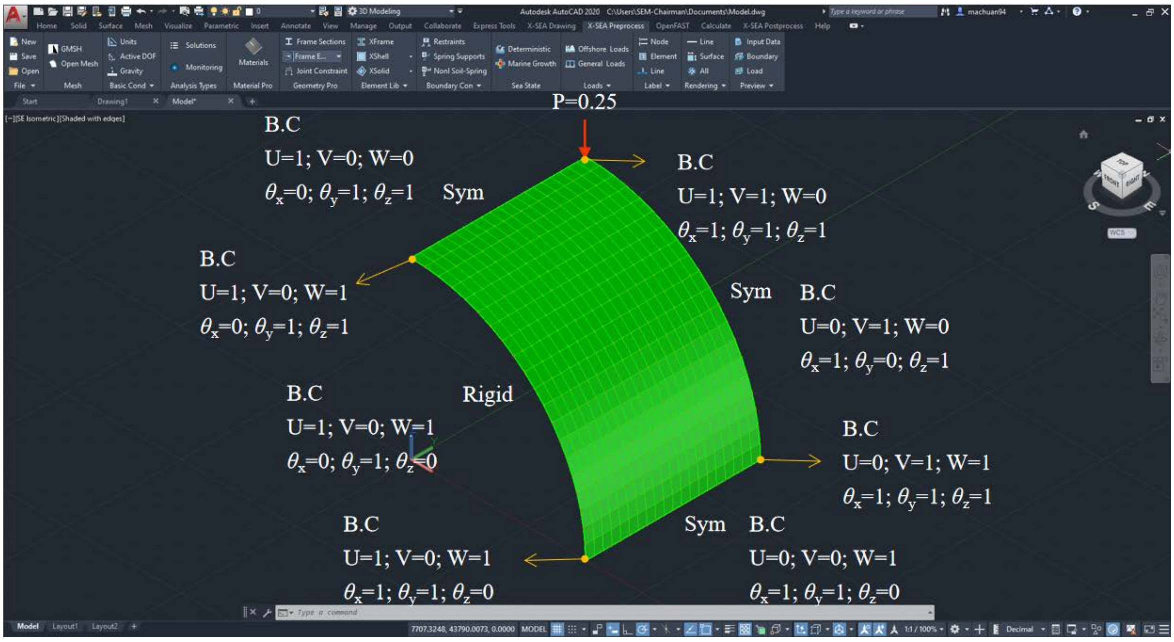


Fig. 3.1 Pinched cylinder and properties (20×20, 4ANS)

Results

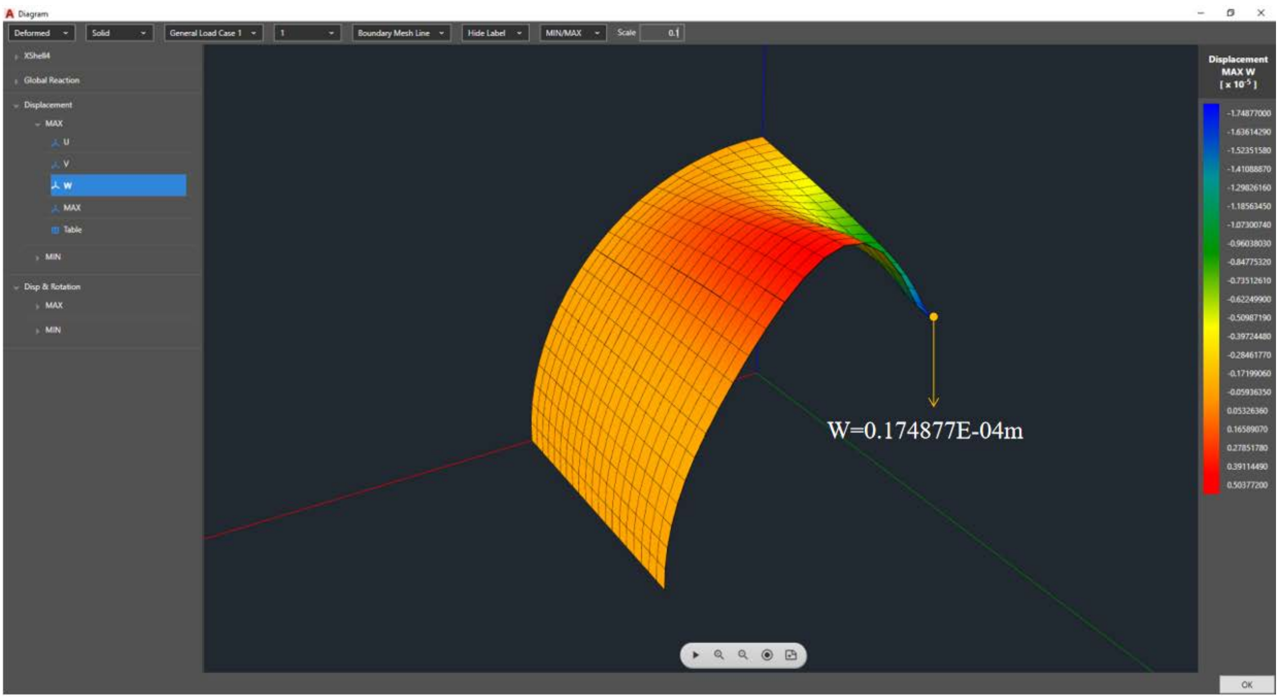
The reference value is 0.18248×10^{-4}. Result with different meshes and elements are presented in table 3.1 & 3.2 and fig.3.1 & 3.2.

Table 3.1 Normalized results of pined cylinder with end diaphragm problem (W = 0.18248 x 10^{-4})

Mesh	S4R5	Simo, et al.	Ma	XSHELL-4-ANS
4x4	-	0.399	0.986	0.387 (0.706325E-05)
6x6	0.6022	-	-	0.621 (0.113282E-04)
8x8	-	0.763	0.997	0.797 (0.145491E-04)
10x10	0.875	-	-	0.831 (0.151691E-04)
16x16	-	0.935	-	0.932 (0.170052E-04)
20x20	0.974	-	-	0.958 (0.174877E-04)

Table 3.2Normalized results of pined cylinder with end diaphragm problem (W = 0.18248 x 10^{-4})

Nodes Per side	Mesh A		Mesh B	
	NLT	XSHELL-3QSI	NLT	XSHELL-3QSI
3	0.033	0.083 (0.150821E-05)	0.033	0.080 (0.146469E-05)
5	0.342	0.518 (0.944946E-05)	0.343	0.510 (0.929848E-05)
9	0.732	0.833 (0.152010E-04)	0.736	0.821 (0.149746E-04)
17	0.904	0.955 (0.174254E-04)	0.907	0.951 (0.173463E-04)
21	0.937	0.970 (0.176936E-04)	0.939	0.969 (0.176795E-04)
33		0.993 (0.181272E-04)		0.991 (0.180749E-04)



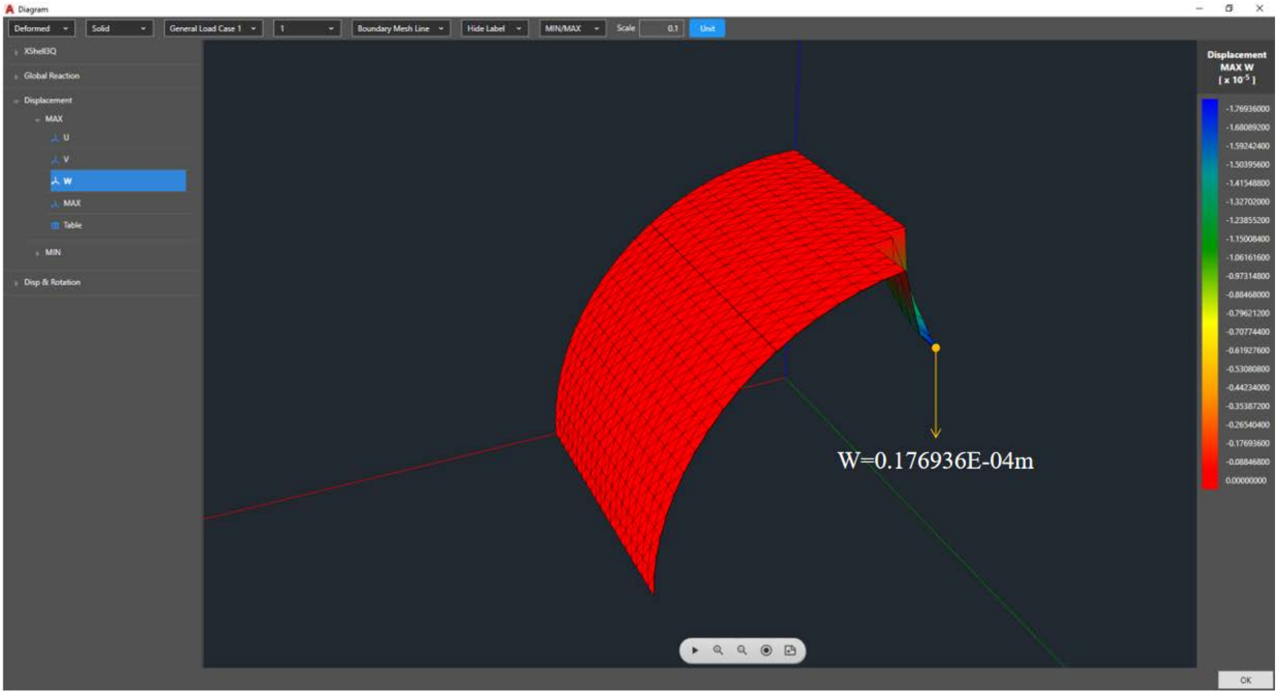


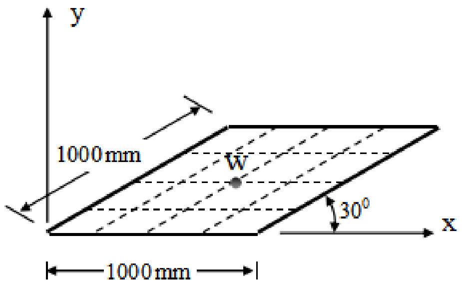
Fig. 3.2 Deflection of pinched cylinder with end diaphragm model (20×20, 4ANS & 20×20, 3QSI)

Verification Example of X-SEA AutoCAD	No: Shell Element 004

Title: Bending of Rhombic Plate

Problem Description

A rhombic plate shown in Fig.4, with simply supports all around, is analyzed for bending. The plate has a thickness of 10mm and side lengths of 1000mm. The material properties are E=30 N/mm^2 and =0.3 and the load is 1.0e^{-6} N/mm^2. Results are obtained and compared (Table 4.1), center deflection (W). The series solution gives deflection W = 0.148 mm.



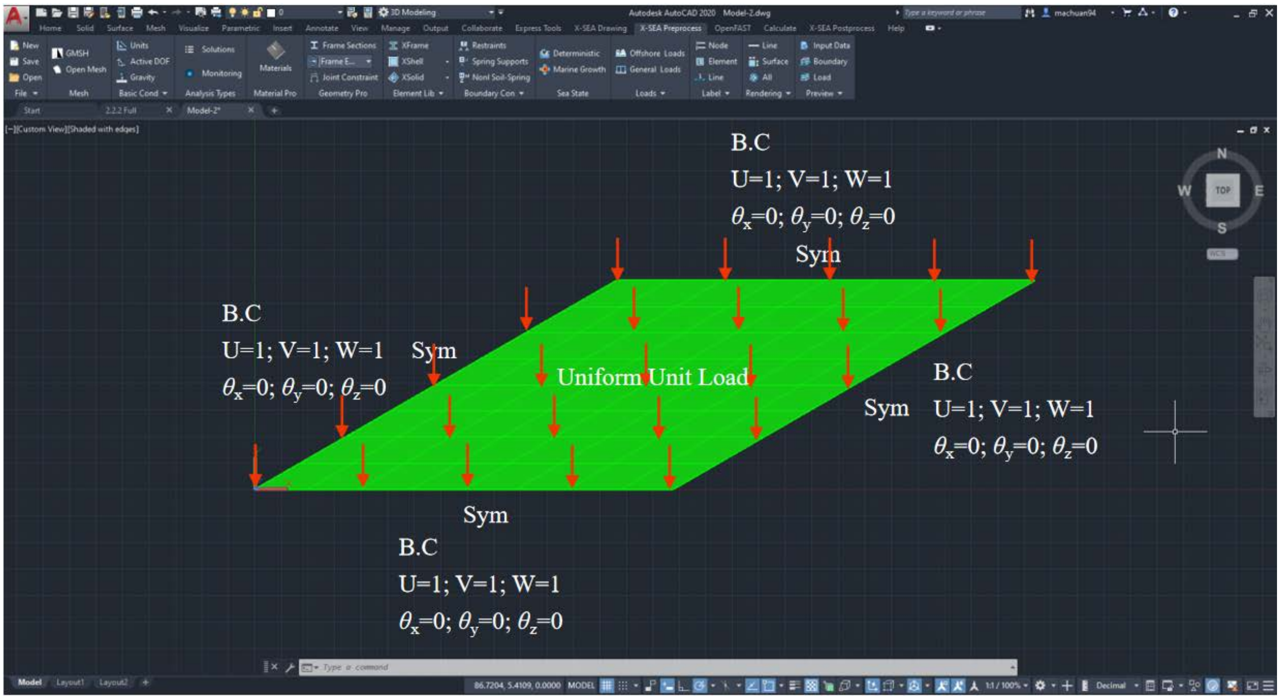


Fig. 4.1 Rhombic plate model (8×8, 4ANS)

Results

Table.4.1 Normalized results of Rhombic plate model (Reference=0.148mm)

Mesh	Normalized Solution at Center	
	S4R5	XSHELL-4-ANS
4x4	1.081	0.880 (0.130234)
8x8	1.081	0.844 (0.124916)
14x14	1.047	0.837 (0.123903)
16x16	-	0.841 (0.124439)

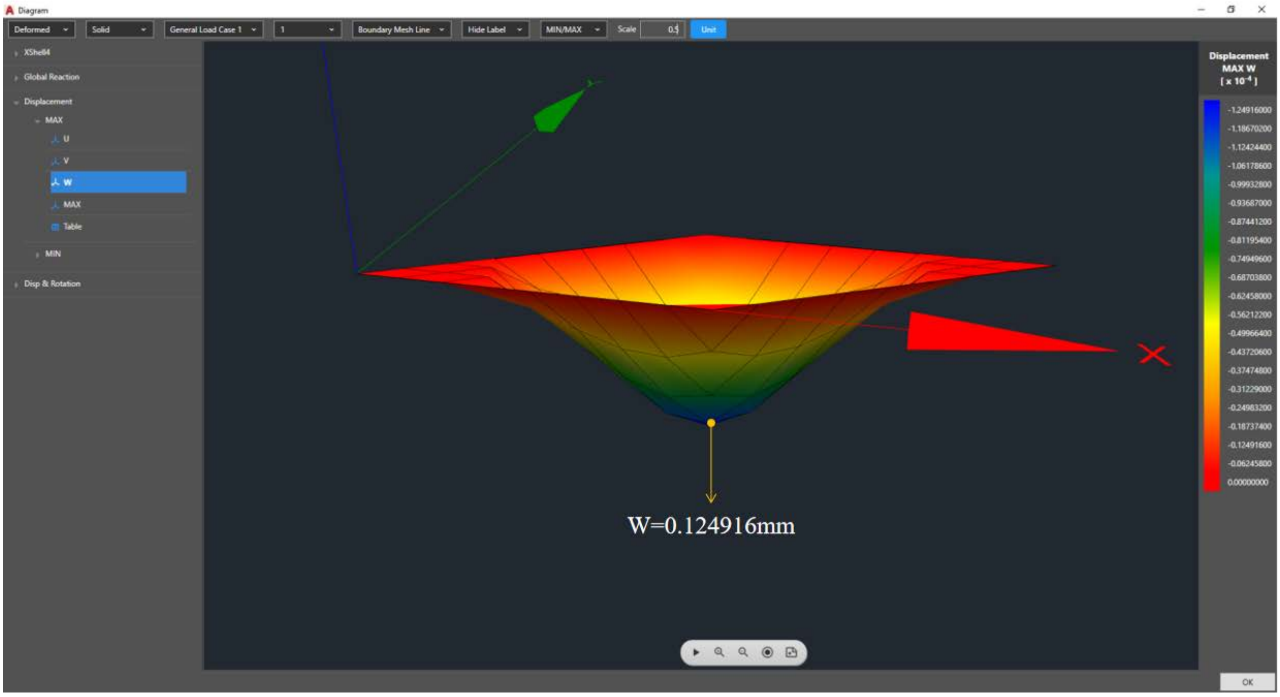


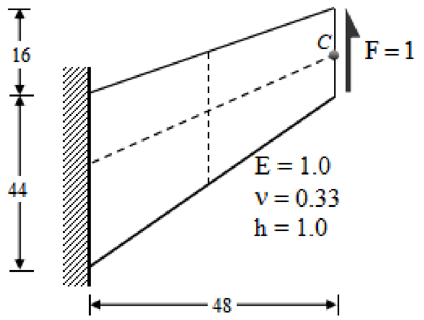
Fig.4.2 Results of Rhombic plate model (8×8, 4ANS)

Verification Example of X-SEA AutoCAD	No: Shell Element 005

Title: Tapered and Swept Beam

Problem Description

A trapezoidal clamped beam with a unit load at the tip was analyzed, Fig.5.1. Elements used to model the beam are distorted and are under membrane forces. The analysis was done using a single element and refined to 16x16 where it converges to the reference solution of 23.91 by Simo et al.[16] (Table 5.1).



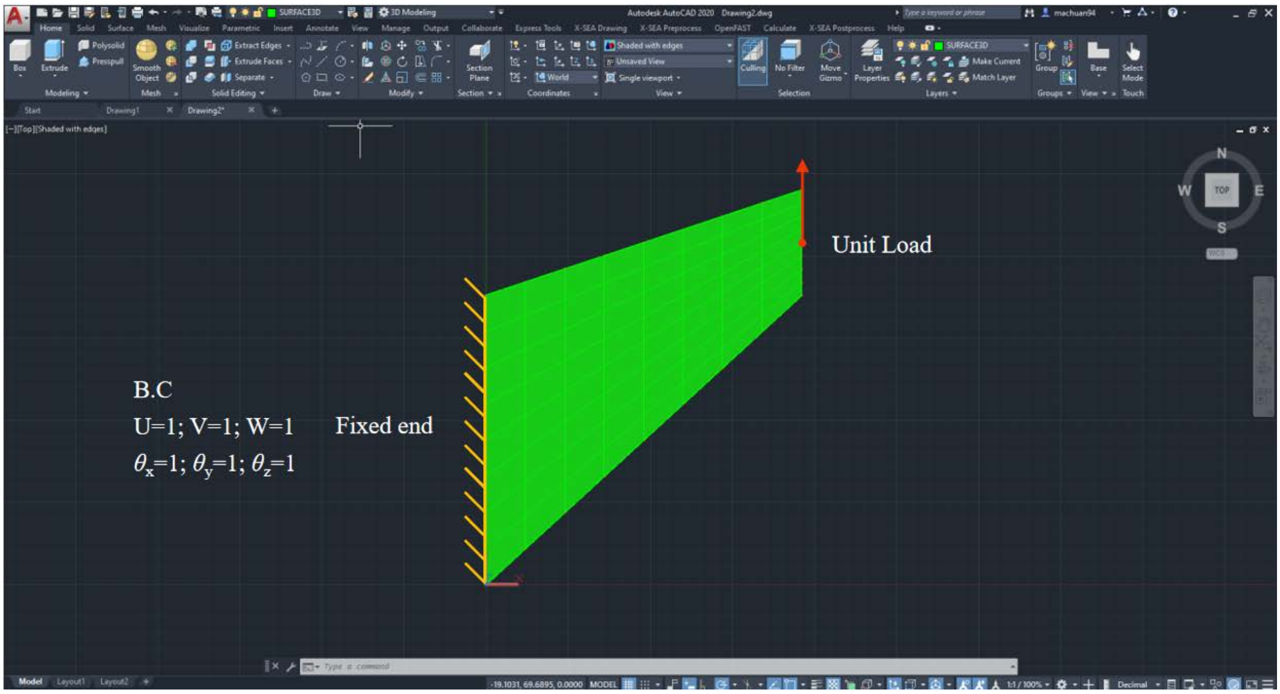


Fig. 5.1 Cook's membrane model (20×20, 4ANS)

Results

Table 5.1 Normalized results to the tapered and swept beam (Reference=23.91)

Mesh	Simo, et al.	Ma	XSHELL-4-ANS
1x1	0.700	0.930	0.738 (17.6536)
2x2	0.883	0.985	0.895 (21.3922)
4x4	0.963	0.998	0.978 (23.3863)
6x6	-	-	1.006 (24.0440)
8x8	0.991	-	1.019 (24.3552)
16x16	0.999	-	1.043 (24.9296)

Table 5.2 Normalized results of three node shell element (Reference=23.91)

Nodes Per side	Mesh A		Mesh B	
	NLT	XSHELL-3QSI	NLT	XSHELL-3QSI
3	0.729	0.718 (17.1624)	0.847	0.831 (19.8585)
5	0.909	0.911 (21.7717)	0.995	0.950 (22.7253)
9	0.995	0.993 (23.7419)	1.013	1.011 (24.1617)
17	1.033	1.033 (24.6913)	1.043	1.042 (24.9232)
25		1.057 (25.0607)		1.056 (25.2534)

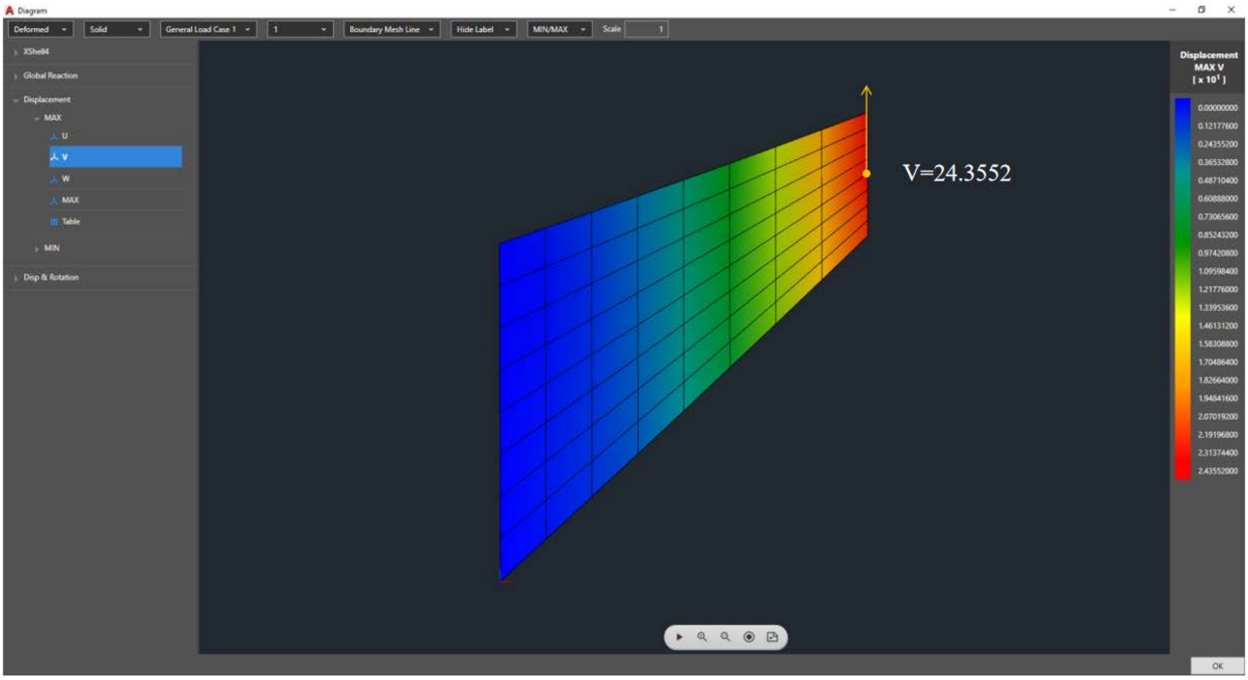


Fig.5.2 Deformation of Cook’s membrane model (20×20, 4ANS)

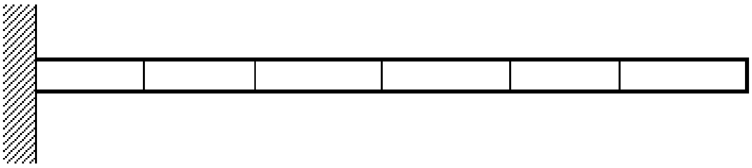
Verification Example of X-SEA AutoCAD	No: Shell Element 006

Title: Cantilever Beam Problem-Straight Beam

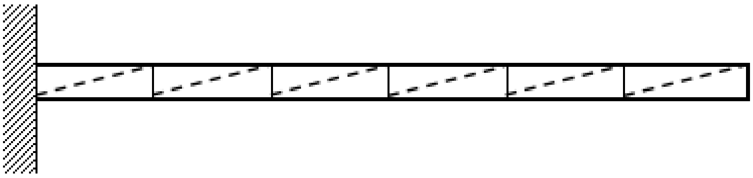
Problem Description

A straight cantilever beam with geometry and material properties shown in Fig.6.1 was analyzed for various loading conditions. MacNeal and Harder (1985) suggested three separate cantilever beam tests that evaluate sensitivity to various deformation patterns and distortions of the element geometry, i.e. a) a straight beam, b) a curved beam and c) a twisted beam.

Length=6.0; Width=0.20; Depth=0.10; E=1.0×10^{7}; v=0.30; Mesh=6×1; Load=Unit load at the end.



(a) Straight Cantilever Beam



(b) Straight Cantilever Beam Mesh for Triangular shell Element

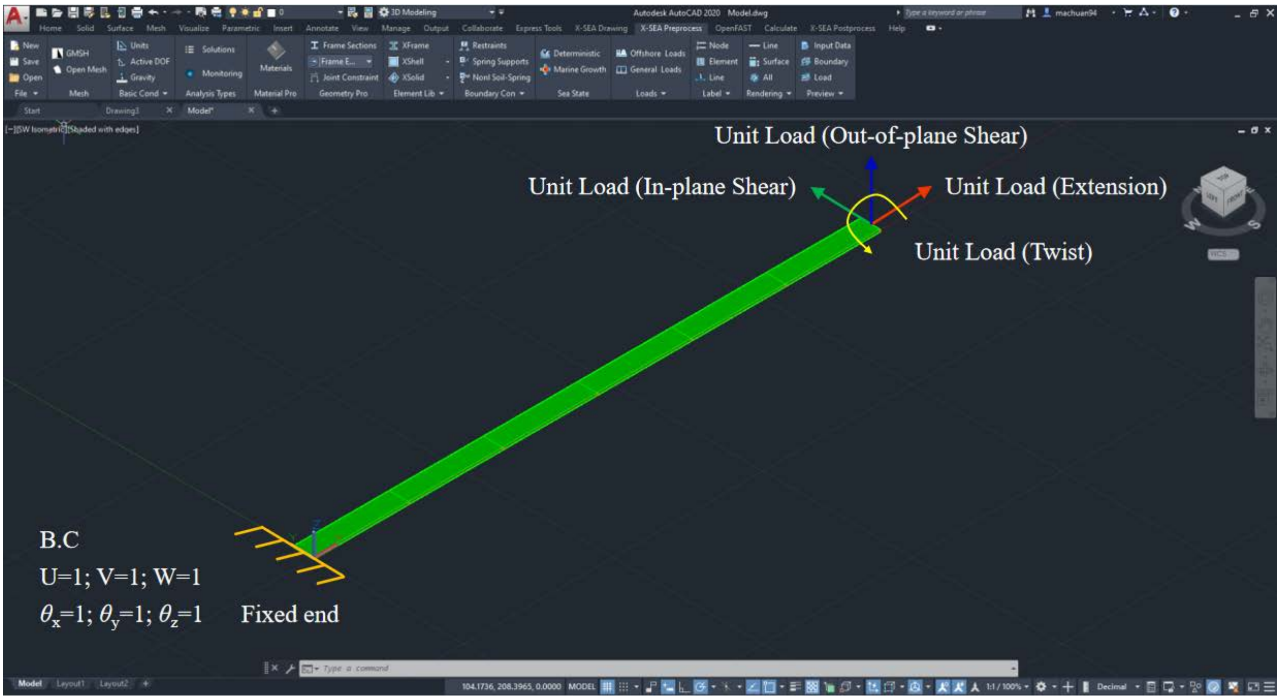


Fig. 6.1 Straight cantilever beam (6×1, 4ANS)

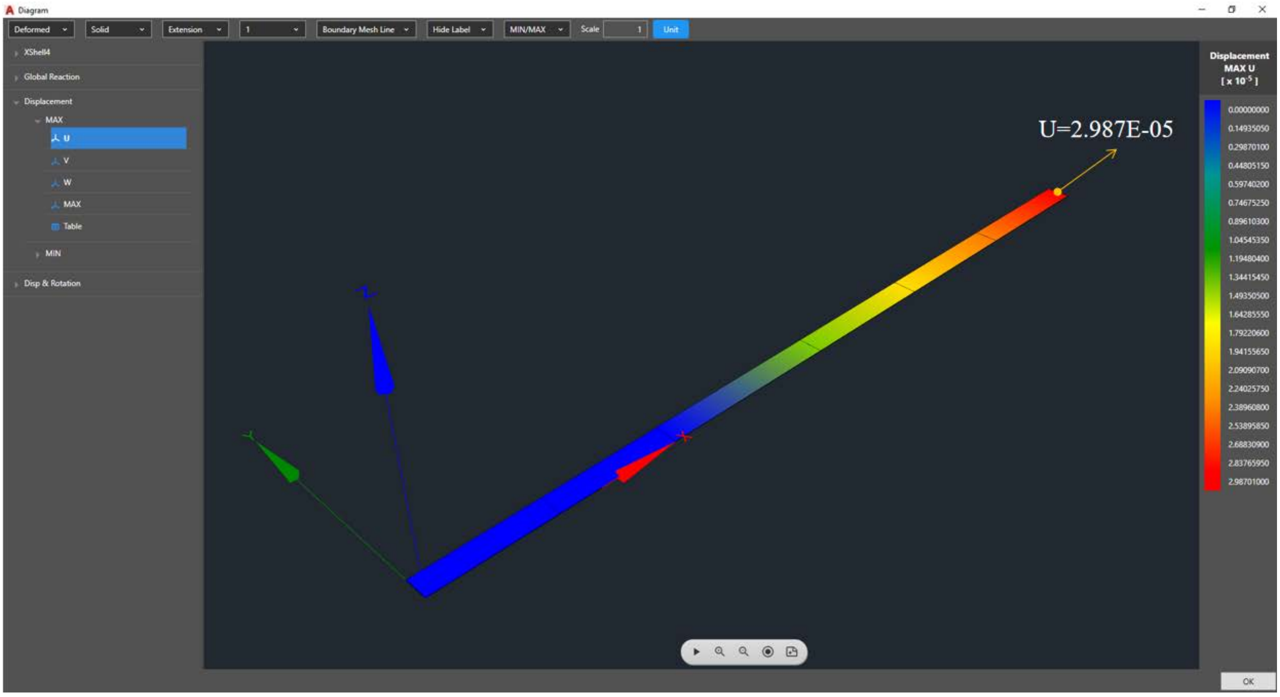
Results

Table 6.1 Normalized results of straight cantilever beam with four node shell element

Load (Analytical Solution)	QUAD 4	Ma	XSHELL-4-ANS (1×6)
Extension (3.0E-05)	0.995	0.998	0.996 (2.987E-05)
In-plane Shear (0.1081)	0.904	0.994	0.970 (0.104820)
Out-of-plane Shear (0.4321)	0.986	0.994	0.980 (0.423486)
Twist (0.03208)	0.941	0.945	0.941 (0.030179)

Table 6.2 Normalized results of straight cantilever beam with three node shell element

Load (Analytical Solution)	Mesh 1×6		
	QUAD2	NLT	XSHELL-3-QSI
Extension (3.0E-05)	0.992	1.00	0.996 (2.987E-05)
In-plane Shear (0.1081)	0.032	0.227	0.223 (0.024065)
Out-of-plane Shear (0.4321)	0.971	0.972	0.976 (0.421909)
Twist (0.03208)	0.566	0.778	0.666 (0.021359)



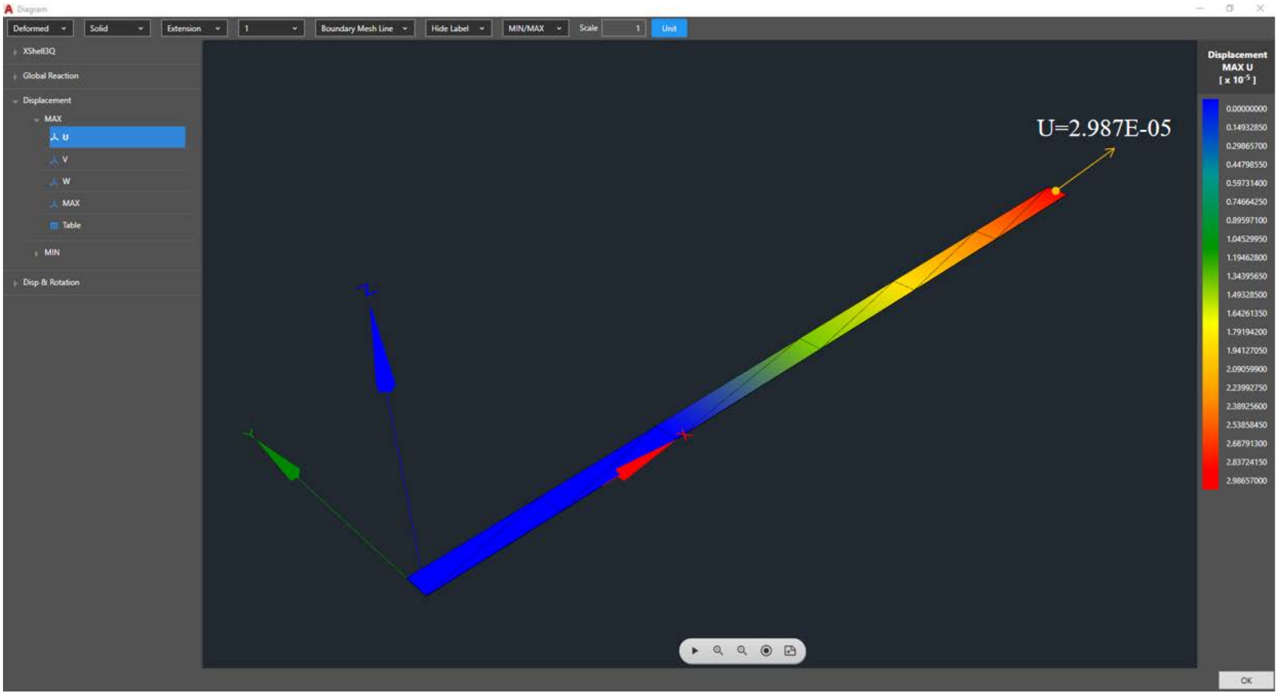
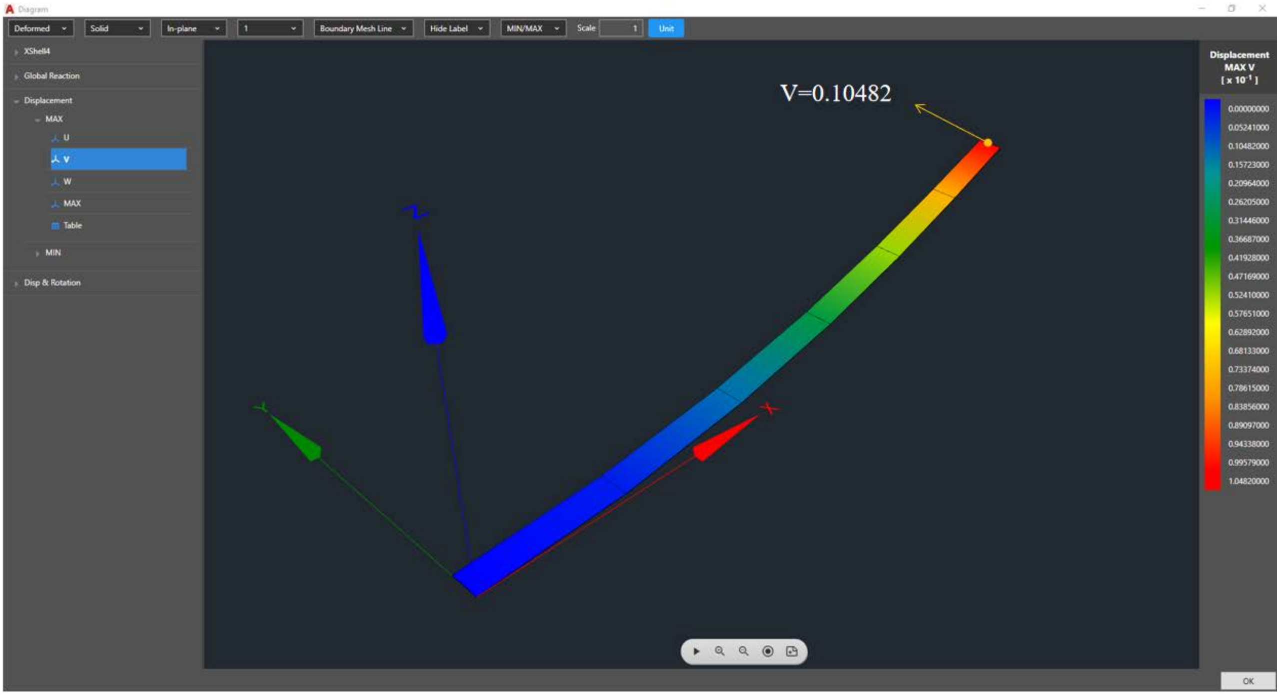


Fig.6.2 Deformation of straight cantilever beam model-U (6×1, 4ANS & 6×1, 3QSI)



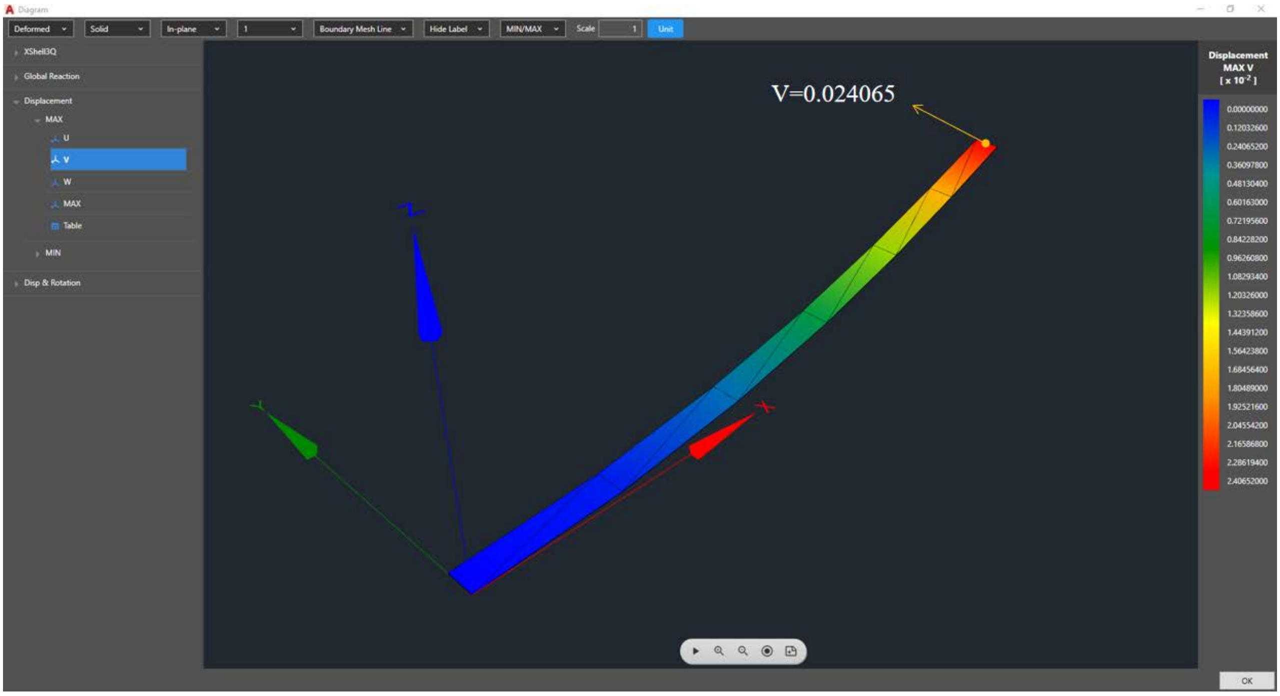
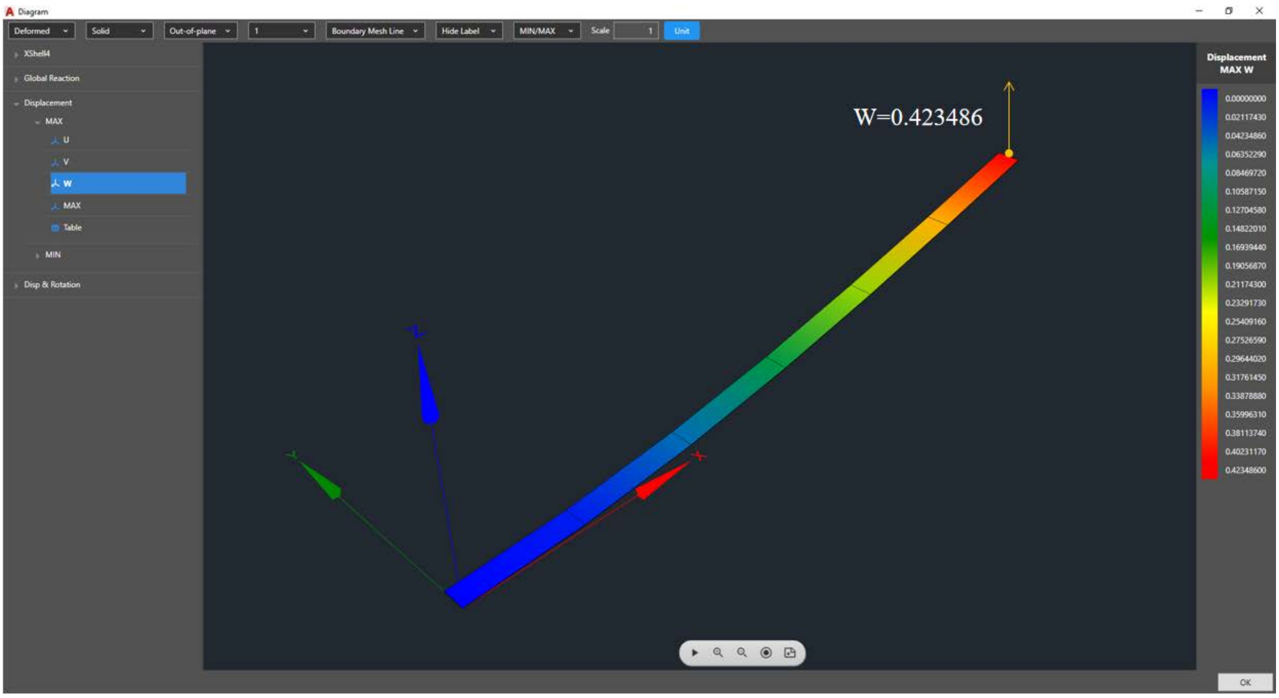


Fig.6.3 Deformation of straight cantilever beam model-V (6×1, 4ANS & 6×1, 3QSI)



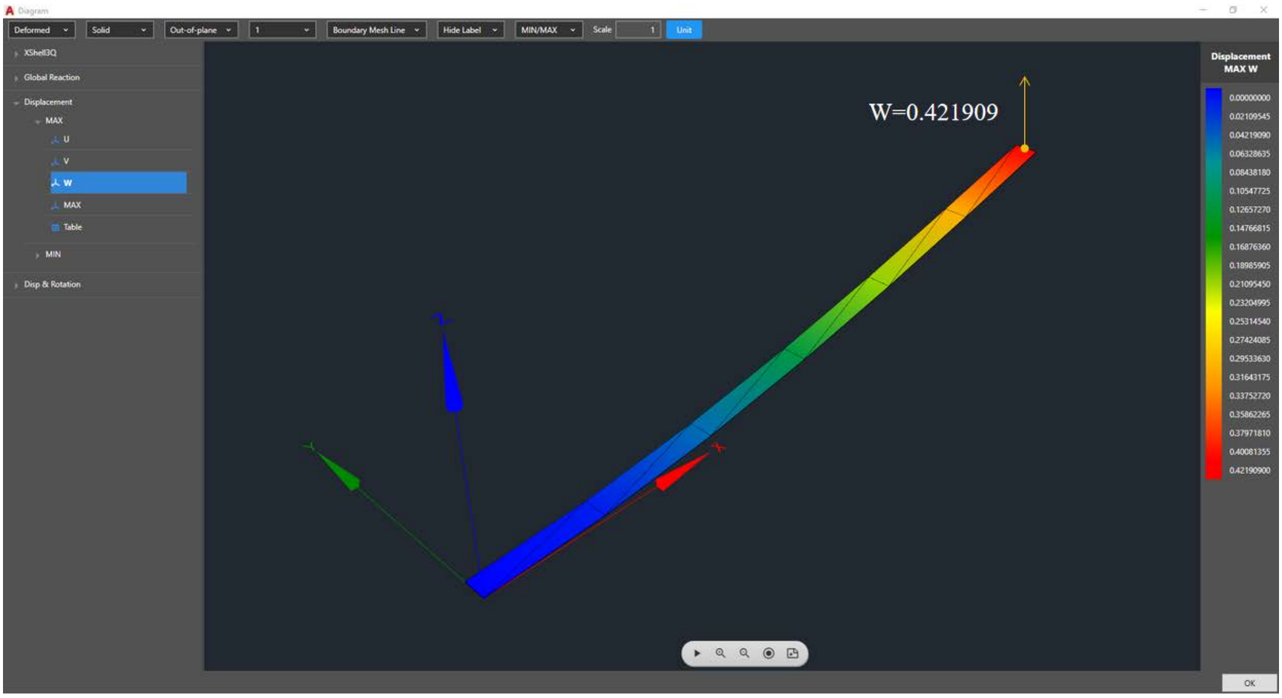
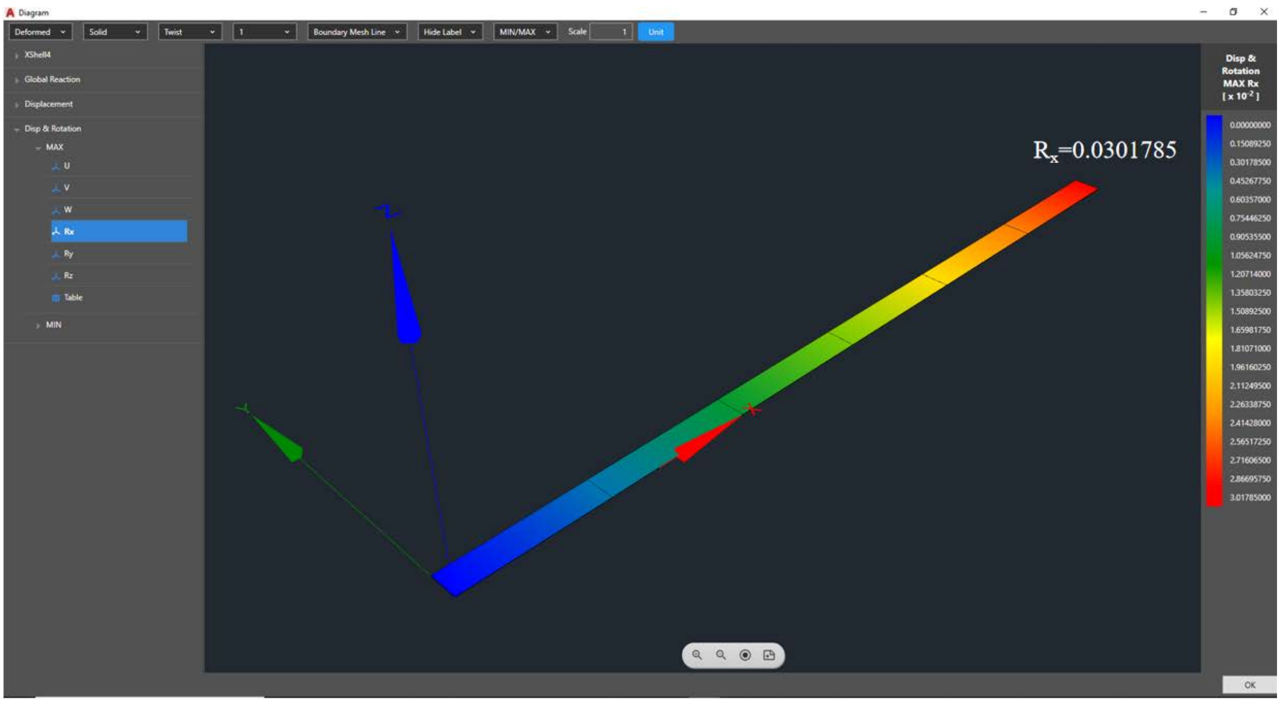


Fig.6.4 Deformation of straight cantilever beam model-W (6×1, 4ANS & 6×1, 3QSI)



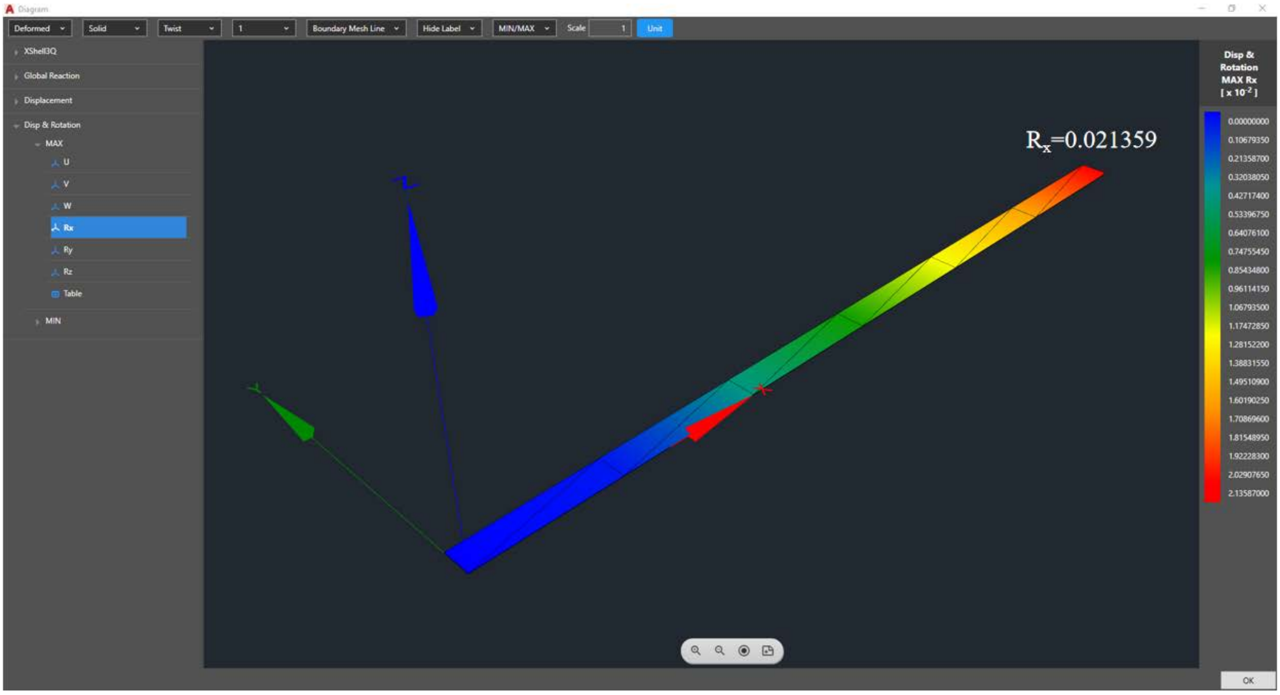


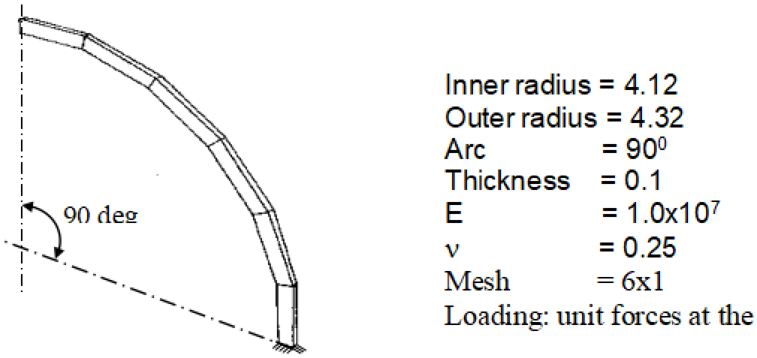
Fig.6.5 Deformation of straight cantilever beam model-R_x (6×1, 4ANS & 6×1, 3QSI)

Verification Example of X-SEA AutoCAD	No: Shell Element 007
Title: Cantilever Beam Problem-Curved Beam	

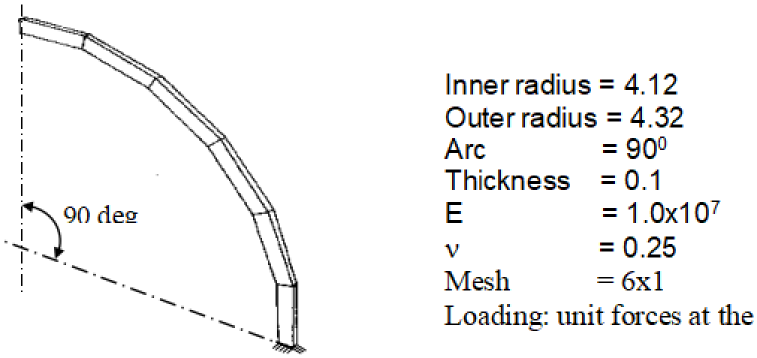
Problem Description

A straight cantilever beam with geometry and material properties shown in Fig.7.1 was analyzed for various loading conditions. MacNeal and Harder (1985) suggested three separate cantilever beam tests that evaluate sensitivity to various deformation patterns and distortions of the element geometry, i.e. a) a straight beam, b) a curved beam and c) a twisted beam.

Length=6.0; Width=0.20; Depth=0.10; E=1.0×10^7; v=0.30; Mesh=6×1; Load=Unit load at the end.



(c) Curve Cantilever Beam and Properties



(d) Curve Cantilever Beam Mesh for Three Node Shell

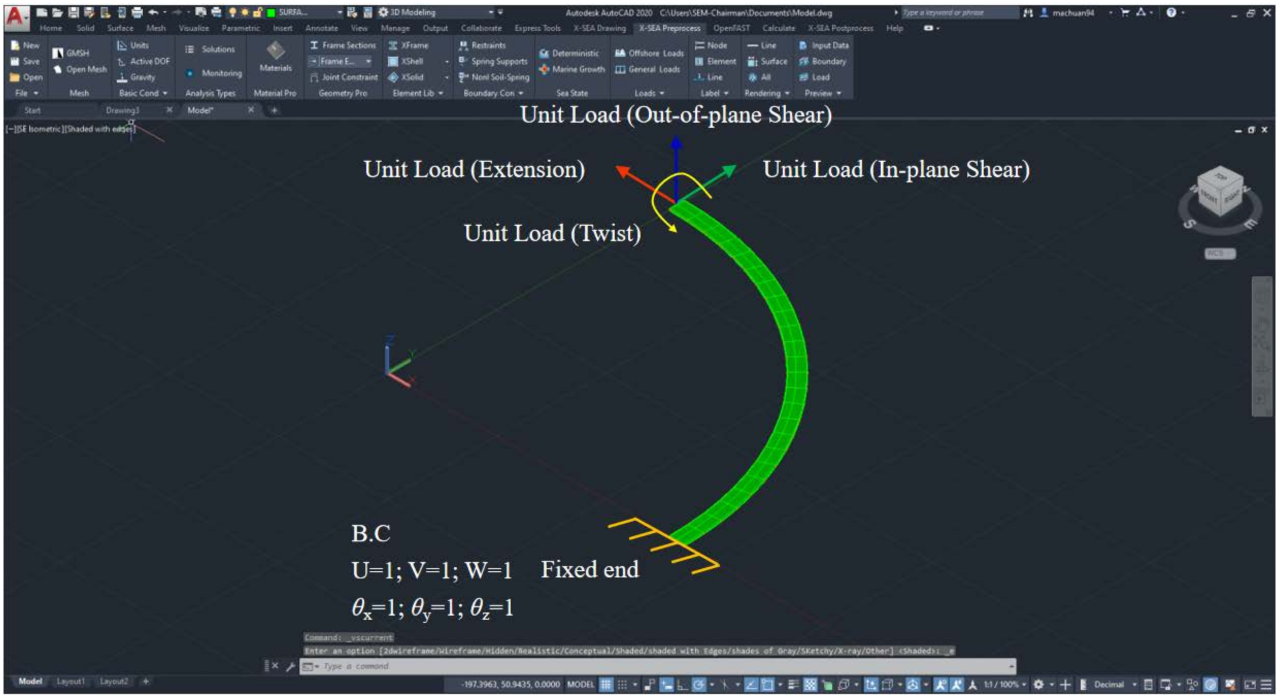


Fig. 7.1 Curved cantilever beam model (2×24, 4ANS)

Results

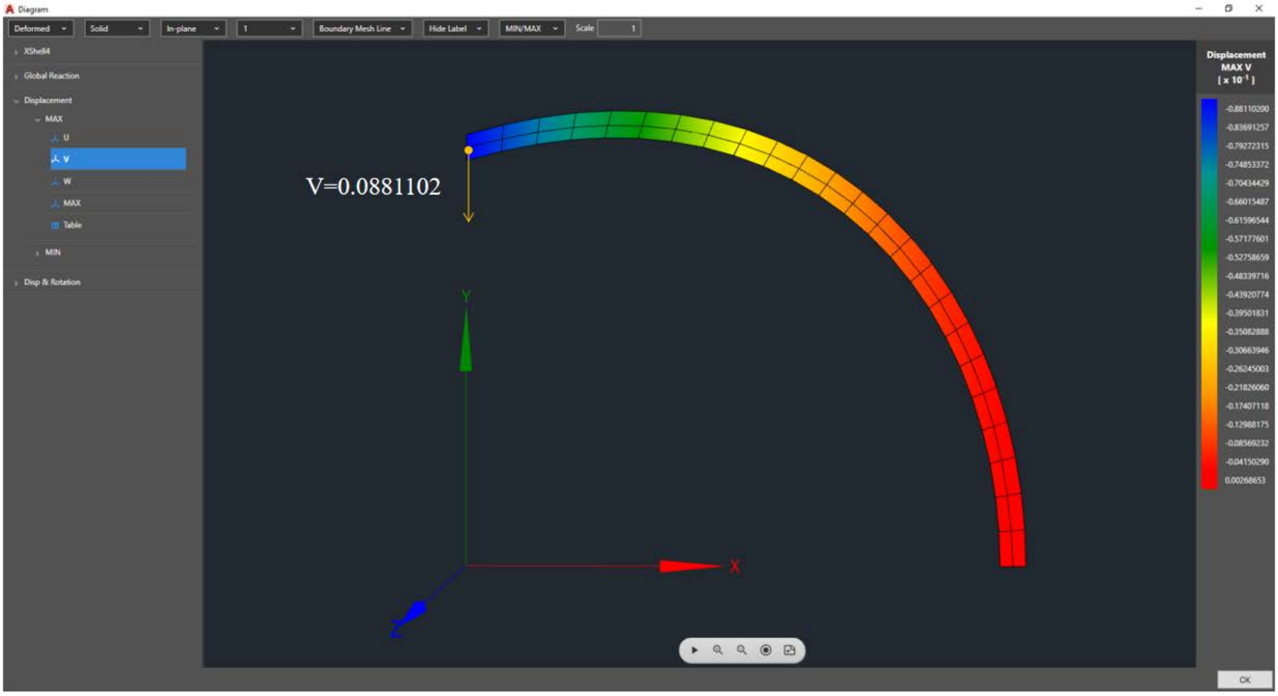
Table 7.1 Normalized results of curved cantilever beam problem

Load (Analytical Solution)	QUAD 4	Ma	XSHELL-4-ANS	
			Mesh	Solution
In-plane Shear (Reference=0.08734)	0.904	0.994	1×06	0.888 (0.077586)
			1×12	0.997 (0.087087)
			1×18	1.007 (0.087987)
Out-of-plane Shear (Reference=0.5022)	0.986	0.994	1×06	0.955 (0.479577)
			1×12	0.968 (0.486003)
			1×18	0.971 (0.487600)
			1×24	0.972 (0.488259)
			2×24	0.972 (0.488388)
			1×36	0.973 (0.488803)

Table 7.2 Normalized results of three node shell element

Load (Analytical Solution)	QUAD 2	STF	NLT	XSHELL-3-QSI	
				Mesh	Solution
In-plane Shear (Reference=0.08734)	0.025	0.952	0.187	1×06	0.185 (0.016159)
	-	-	0.759	1×30	0.720 (0.062925)
	-	-	0.936	2×60	0.920 (0.080314)
	-	-	-	3×100	0.973 (0.085006)
Out-of-plane Shear	0.594	0.905	0.851	1×06	0.766 (0.384616)

(Reference=0.5022)	- - -	- - -	0.911 0.925 -	1×30 2×60 3×100	0.915 (0.459308) 0.939 (0.471646) 0.963 (0.483433)



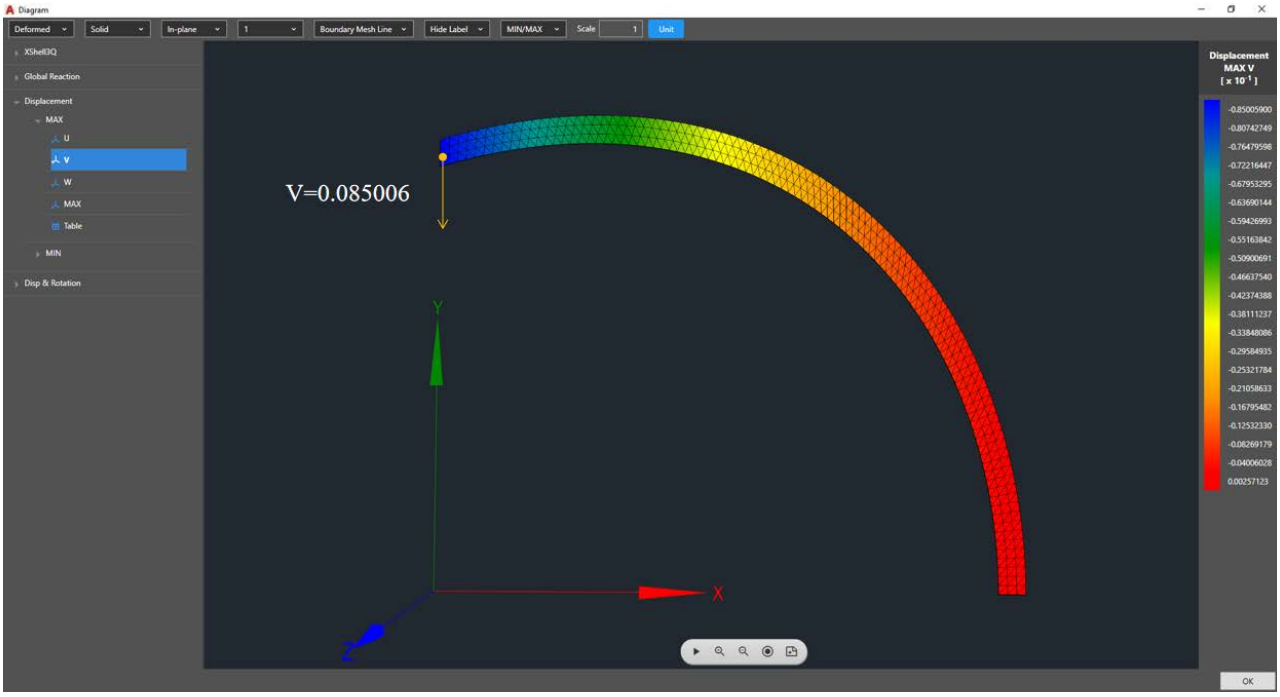
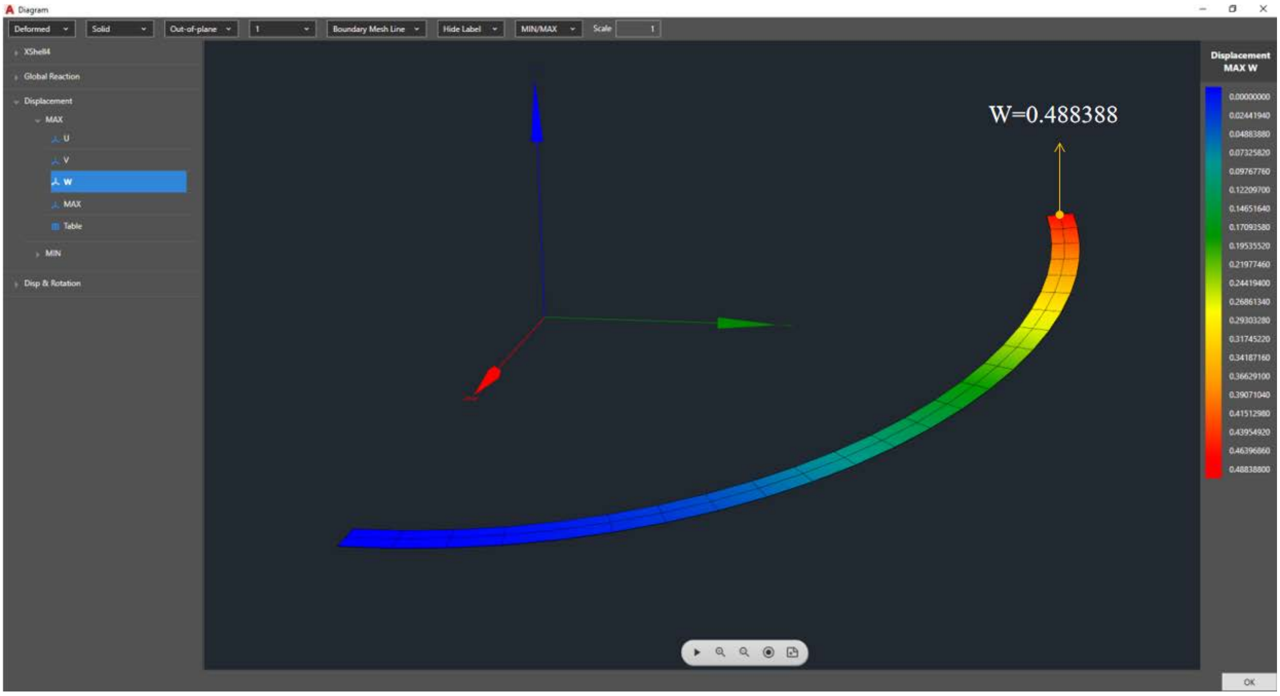


Fig.7.2 Deformation of curved cantilever beam model-V (2×24, 4ANS & 3×100, 3QSI)



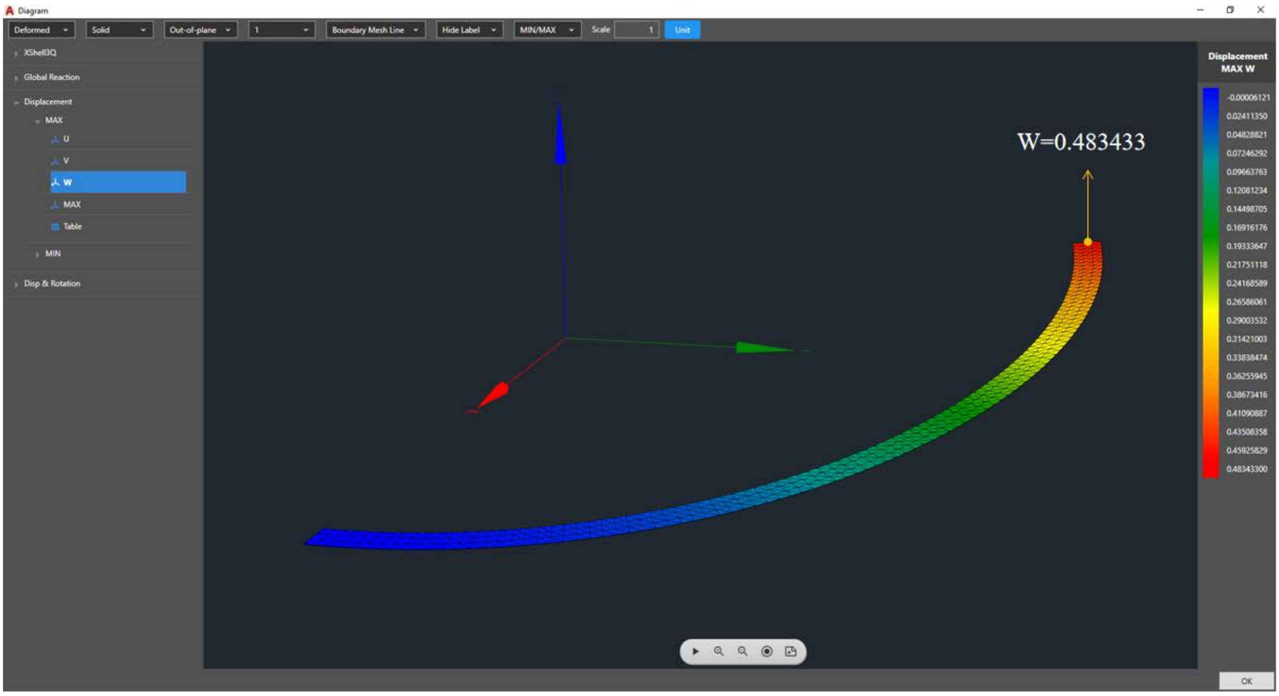


Fig.7.3 Deformation of curved cantilever beam model-W (2×24, 4ANS & 3×100, 3QSI)

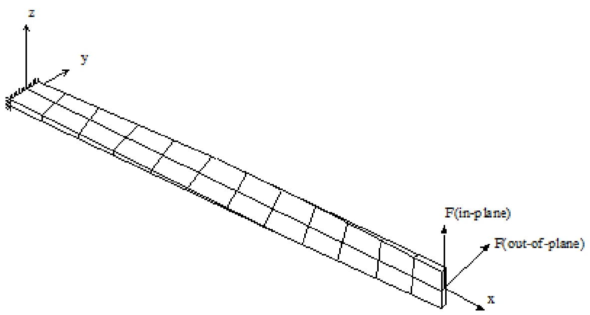
Verification Example of X-SEA AutoCAD	No: Shell Element 008

Title: Cantilever Beam Problem-Twisted Beam

Problem Description

A straight cantilever beam with geometry and material properties shown in Fig.8.1 was analyzed for various loading conditions. MacNeal and Harder (1985) suggested three separate cantilever beam tests that evaluate sensitivity to various deformation patterns and distortions of the element geometry, i.e. a) a straight beam, b) a curved beam and c) a twisted beam.

Length=12.0; Width=1.10; Depth=0.32/0.05; E=2.9×10^7; v=0.22; Load=Unit load at the end.



Length = 12.0

Width = 1.10

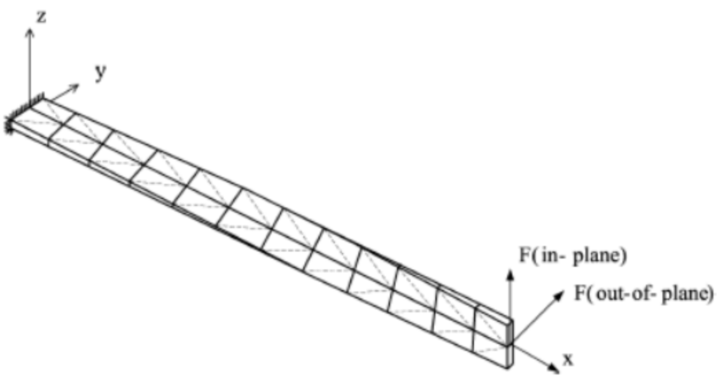
Thickness = 0.32 / 0.05

E = $29.0\text{x}10^6$

ν = 0.22

Twist = 90 deg (root to tip)

(e) Twisted Cantilever



(f) Twisted Cantilever Beam for Three Node shell element

For both cases, the present elements with the warping correction by Taylor, provide good results even with rough meshes.

The solution given by MacNeal and Harder[14] for the beam with t = 0.32 are: in-plane shear-0.005424 and out-of-plane shear- 0.001754.

The solution for the thin beam is taken from Simo et al., in-plane shear-1.390 and out-of-plane shear-0.3439 for case of t = 0.05.

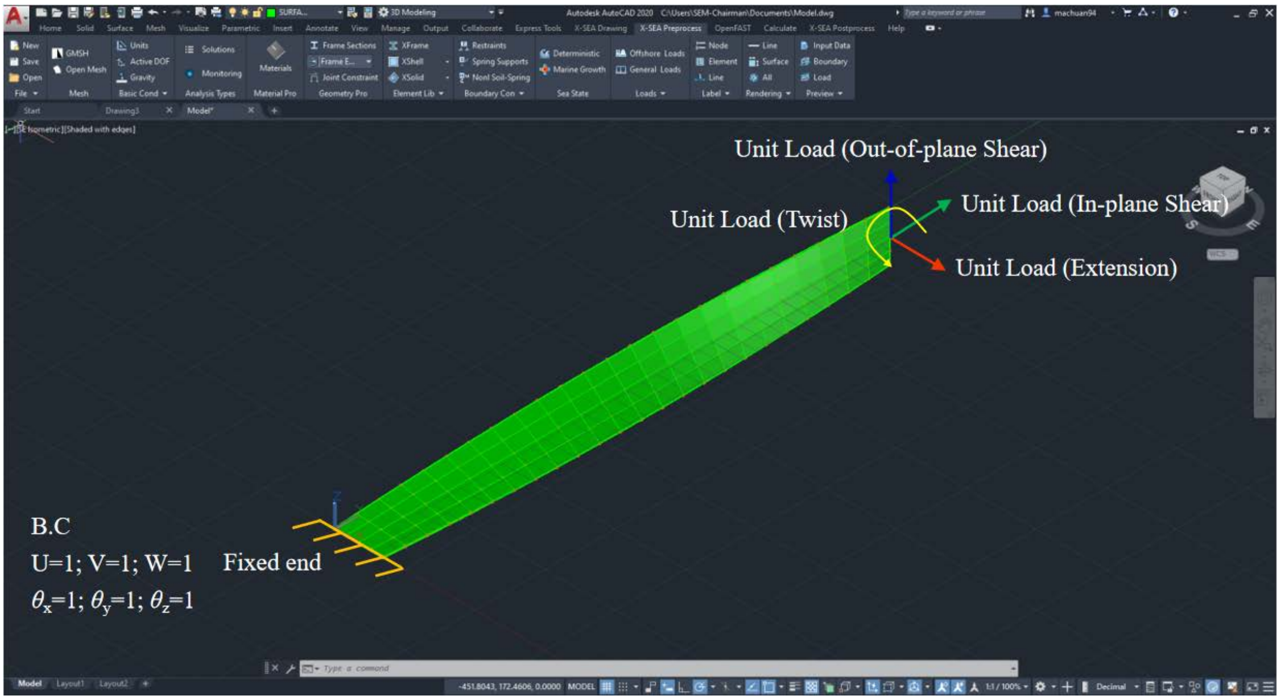


Fig. 8.1 Twisted cantilever beam model (4×24, 4ANS)

Results

Table 8.1 Normalized results of twisted cantilever beam problem T=0.32
(Reference: in-plane shear-0.005424 & out-of-plane shear-0.001754)

Mesh	QUAD 4		XSHELL-4-ANS	
	In-plane Shear	Out-of-plane Shear	In-plane Shear	Out-of-plane Shear
1×06	-	-	1.020 (0.553317E-02)	0.982 (0.172290E-02)
2×12	0.991	0.985	1.027 (0.557133E-02)	1.014 (0.177921E-02)
4×24	-	-	1.030 (0.558791E-02)	1.023 (0.179473E-02)
8×48	-	-	1.032 (0.559501E-02)	1.026 (0.179895E-02)

Table 8.2 Normalized results of twisted cantilever beam problem T=0.05
(Reference: in-plane shear-1.390 & out-of-plane shear-0.3439)

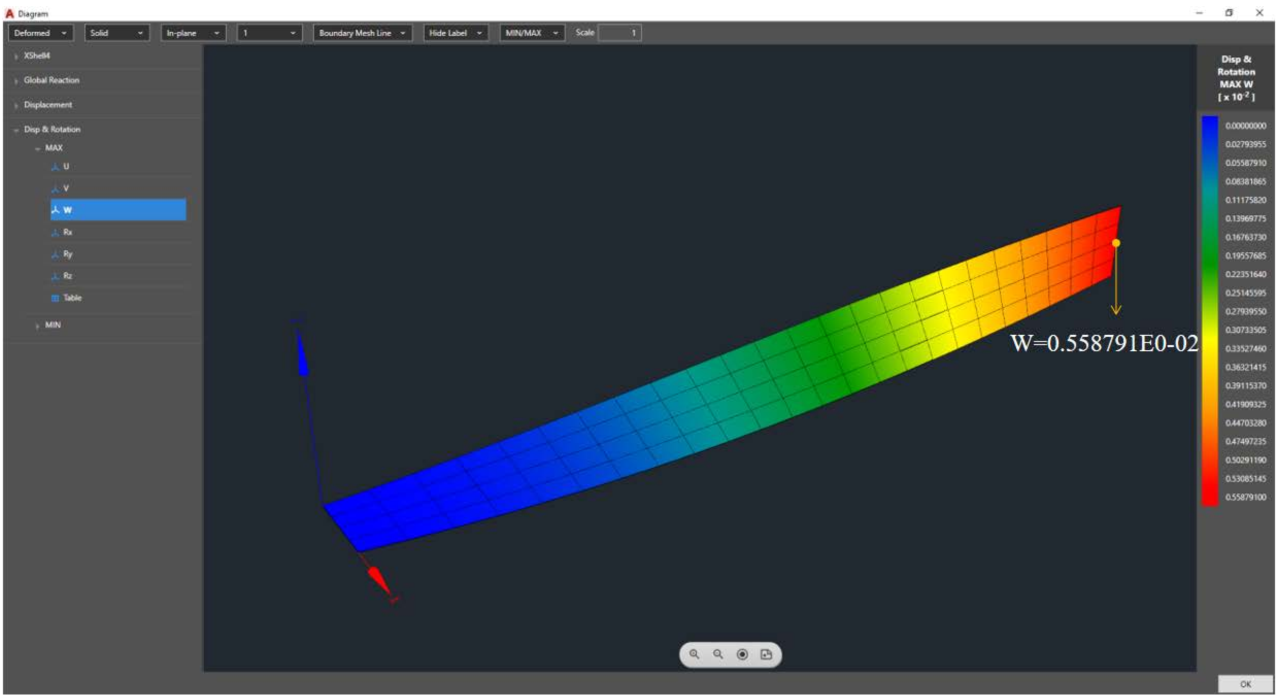
Mesh	Simo et al.		XSHELL-4-ANS	
	In-plane Shear	Out-of-plane Shear	In-plane Shear	Out-of-plane Shear
1×06	0.991	0.951	0.971 (1.349840)	0.932 (0.320618)
2×12	0.998	0.986	0.995 (1.382490)	0.982 (0.337855)
4×24	0.999	0.997	0.998 (1.387390)	0.994 (0.341983)
8×48	-	-	0.998 (1.387470)	0.997 (0.342871)

Table 8.3 Normalized results of twisted cantilever beam problem T=0.32
(Reference: in-plane shear-0.005424 & out-of-plane shear-0.001754)

Mesh	NLT		STF		XSHELL-3-QSI	
	In-plane Shear	Out-of-plane Shear	In-plane Shear	Out-of-plane Shear	In-plane Shear	Out-of-plane Shear
2×12	0.995	1.039	0.982	1.036	0.988 (0.536018E-02)	0.964 (0.169034E-02)
4×24	-	-	-	-	1.015 (0.550562E-02)	1.043 (0.182894E-02)
8×48	-	-	-	-	1.173 (0.636412E-02)	1.344 (0.235662E-02)

Table 8.3 Normalized results of twisted cantilever beam problem T=0.05
(Reference: in-plane shear-1.390 & out-of-plane shear-0.3439)

Mesh	QUAD 4		XSHELL-3-QSI	
	In-plane Shear	Out-of-plane Shear	In-plane Shear	Out-of-plane Shear
2×12	0.775	0.741	0.820 (1.14020)	0.831 (0.285718)
4×24	0.862	0.880	0.983 (1.36603)	0.983 (0.338068)
8×48	0.882	0.931	0.997 (1.38613)	0.997(0.342892)



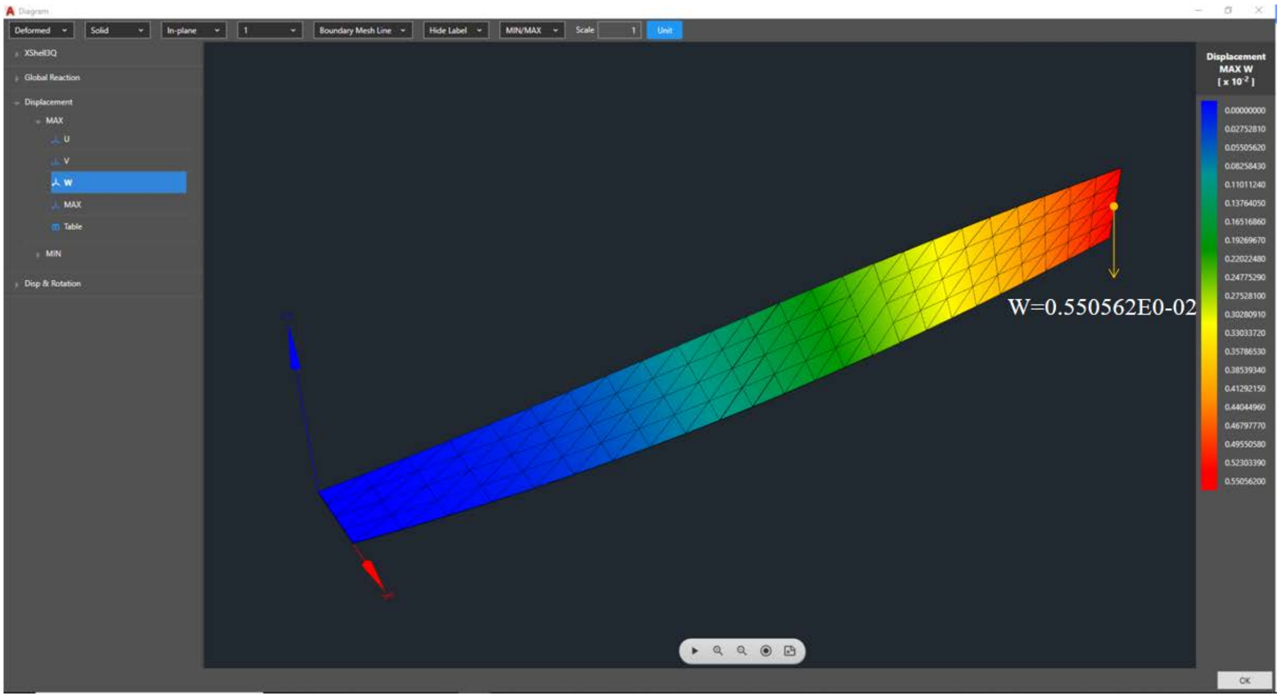
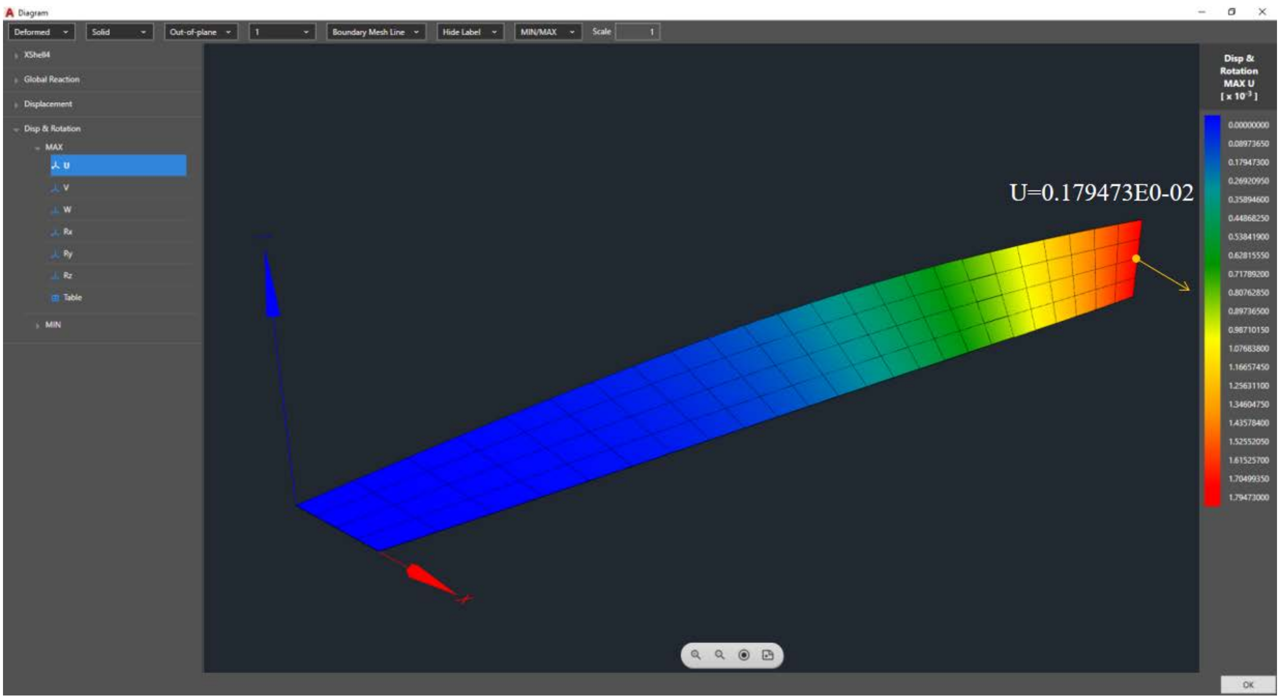


Fig.8.2 Deformation of curved cantilever beam model-W (T=0.32, 4×24, 4ANS & 4×24, 3QSI)



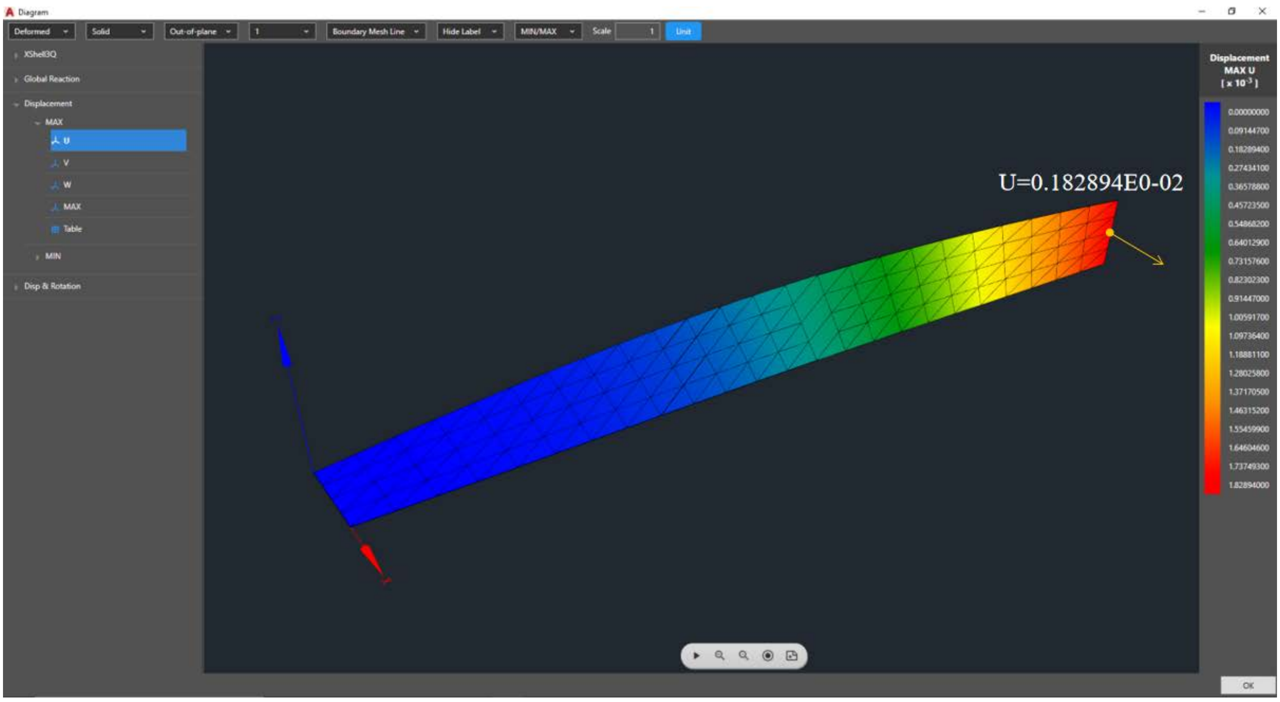


Fig.8.3 Deformation of curved cantilever beam model-U (T=0.32, 4×24, 4ANS & 4×24, 3QSI)

Verification Example of X-SEA AutoCAD	No: Shell Element 009

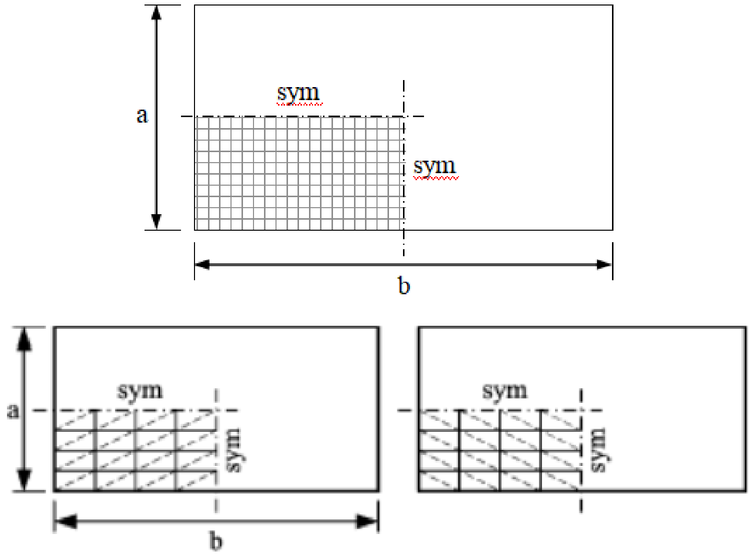
Title: Plate Bending Problem with Clamped Boundary Condition

Problem Description

The clamped rectangular plates subjected to a uniform distributed loading are carried out for aspect ratio of 1.0. The plates are modeled by employing quarter symmetry. The finite element mesh of 4x4 elements is used for all the cases. The central deflection theory from thin plate theory with clamped edges by Timoshenko and Woinowosky-Krieger (1959) is

$$\delta = \frac{0.00126qa^4}{D} = 0.72576\text{E-3}$$

where q is a uniform loading intensity, a is length and D is rigidity.
a=2.0; b=2 or 10; t=0.0001; E=1.7472×10^7; v=0.30; Mesh=n×n(1/4 sym model); Load=P=4E-04.



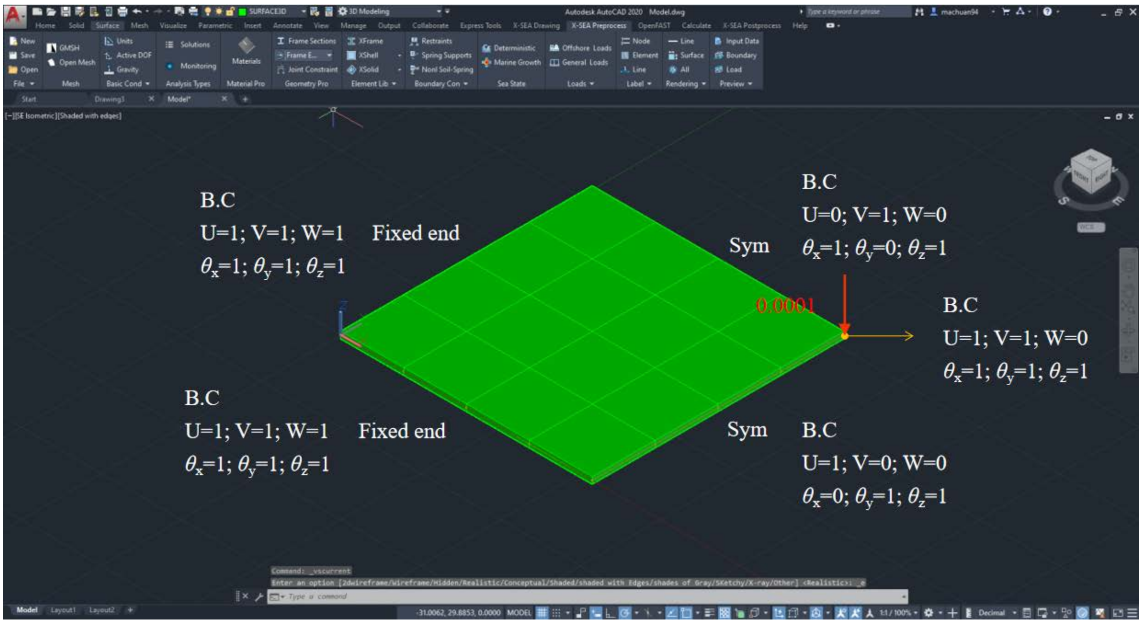


Fig. 9.1 Clamped plate model (a/b=1, 4×4, 4ANS)

Results

Table 9.1 Normalized results for the clamped plate problem a/b=1 of 4ANS

Mesh	a/b=1 (w=5.60 vertical displacement)	
	QUAD 4	XSHELL-4-ANS
2×2	0.934	0.865 (4.84496)
4×4	1.010	0.965 (5.40373)
6×6	1.012	0.985 (5.51423)
8×8	1.010	0.985 (5.55464)
16×16	-	0.999 (5.59619)

Table 9.2 Normalized results for the clamped plate problem a/b=0.2 of 4ANS

Mesh	a/b=0.2 (w=7.23 vertical displacement)	
	QUAD 4	XSHELL-4-ANS
2×2	0.519	0.318 (2.30152)
4×4	0.863	0.825 (5.96780)
6×6	0.940	0.900 (6.58878)
8×8	0.972	0.946 (6.84069)
16×16	-	0.985 (7.12185)

Table 9.3 Normalized results for the clamped plate problem a/b=1 of 3QSI

Mesh	a/b=1 (w=5.60 vertical displacement)					
	QUAD 2	STF	Mesh A		Mesh B	
			NTL	XSHELL-3-QSI	NTL	XSHELL-3-QSI
2×2	0.979	-	0.759	0.837 (4.68512)	0.759	0.897 (5.02216)
3×3	-	1.065	0.874	0.924 (5.17239)	0.882	0.951 (5.32289)
4×4	1.008	-	0.923	0.955 (5.34800)	0.929	0.972 (5.44074)
6×6	1.006	-	0.963	0.979 (5.48463)	0.967	0.988 (5.53166)
8×8	1.005	-	0.978	0.989 (5.53652)	0.981	0.994 (5.56513)

Table 9.4 Normalized results for the clamped plate problem a/b=0.2 of 3QSI

Mesh	a/b=0.2 (w=7.23 vertical displacement)					
	QUAD 2	STF	Mesh A		Mesh B	
			NTL	XSHELL-3-QSI	NTL	XSHELL-3-QSI
2×2	0.773	-	0.283	0.358 (2.59059)	0.759	0.375 (2.71383)
3×3	-	1.740	0.539	0.538 (3.88711)	0.882	0.568 (4.10922)
4×4	0.968	-	0.680	0.666 (4.87219)	0.929	0.715 (5.17097)
6×6	0.993	-	0.814	0.826 (5.96884)	0.967	0.867 (6.26661)
8×8	0.998	-	0.879	0.891 (6.44210)	0.981	0.920 (6.64966)

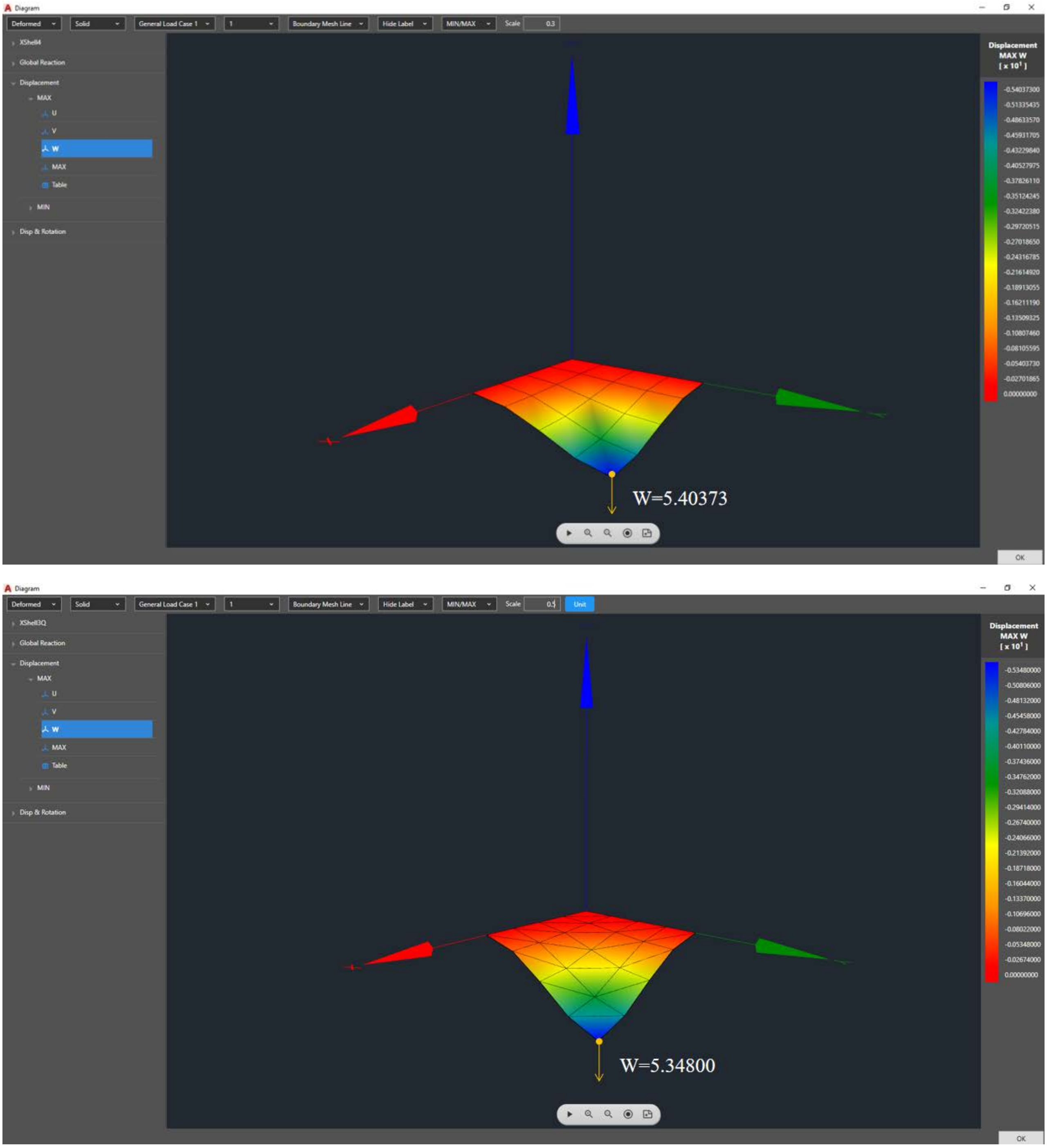


Fig.9.2 Deformation of clamped plate model-W (a/b=1, 4×4, 4ANS & 4×4, 3QSI)

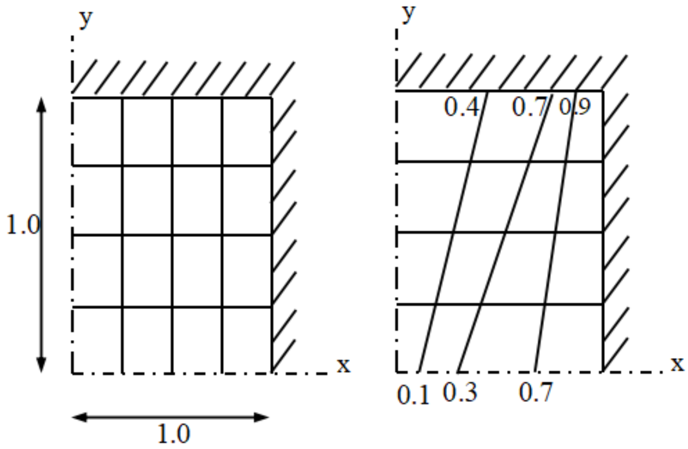
Verification Example of X-SEA AutoCAD	No: Shell Element 010

Title: Square plate with regular and distorted mesh

Problem Description

A clamped boundary condition is chosen because it is considered to be more severe compared to simple supports. Two types of loading are considered, point load and distributed load. A four by four mesh is used on one quarter of the plate. The results are compared in Table 10.1 to those provided by Timoshenko and Woinowsky-Krieger (1959). The accuracy of the results obtained for both cases is maintained and compared with Choi, et al.[7].

t=0.0001; E=1.7472×10^7; v=0.30; Mesh=n×n(1/4 sym model); Load: P=4.0E-04, q=1.0E-04;



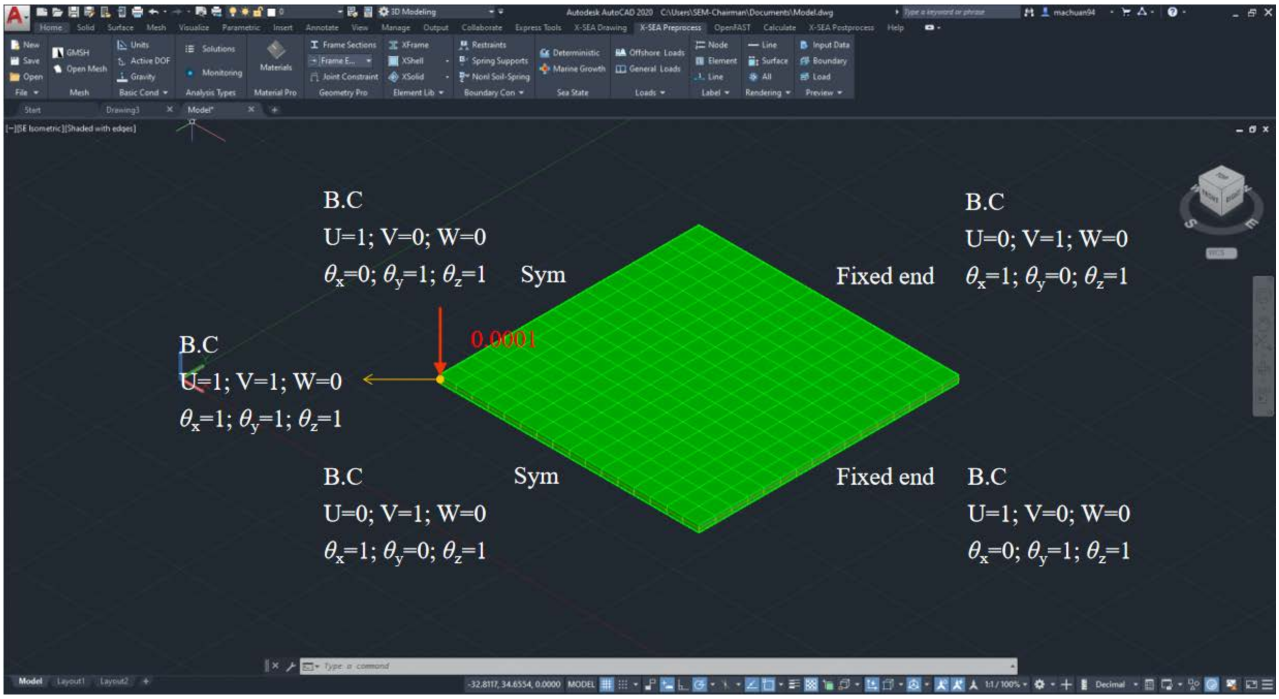


Fig. 10.1 Clamped square plates model with regular meshes (16×16, 4ANS)

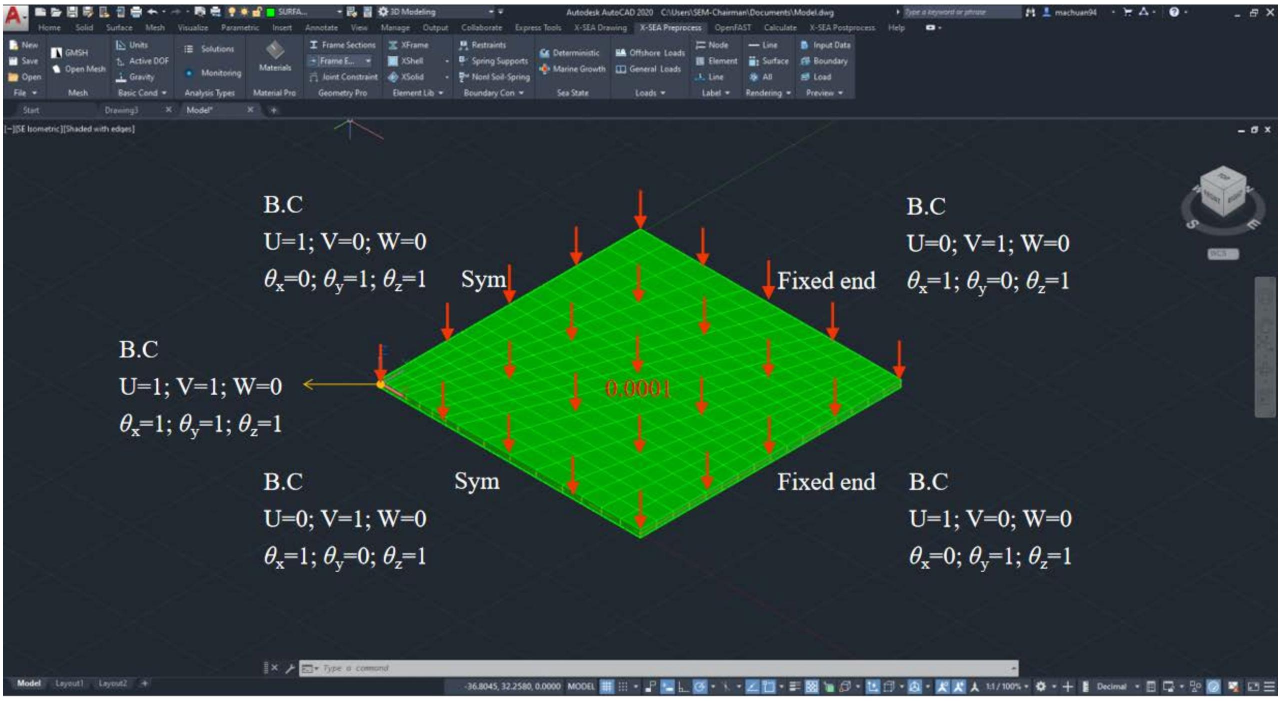


Fig. 10.2 Clamped square plates model with distorted meshes (16×16, 4ANS)

Results

Table 10.1 Normalized results of clamped plate with regular and distorted mesh

Type	Mesh	Elements	Point Load (Reference=5.60)	Uniform Load (Reference=1.2637)
Regular Mesh	XSHELL-4-ANS	4×4	0.965 (5.40373)	0.990 (1.25069)
		8×8	0.992 (5.55464)	0.998 (1.26165)
		16×16	0.999 (5.59619)	1.001 (1.26440)
	Choi et al.	-	0.990	0.965
Disored Mesh	XSHELL-4-ANS	4×4	0.977 (5.47061)	1.011 (1.27816)
		8×8	0.995 (5.57159)	1.004 (1.26861)
		16×16	1.000 (5.60103)	1.002 (1.26617)

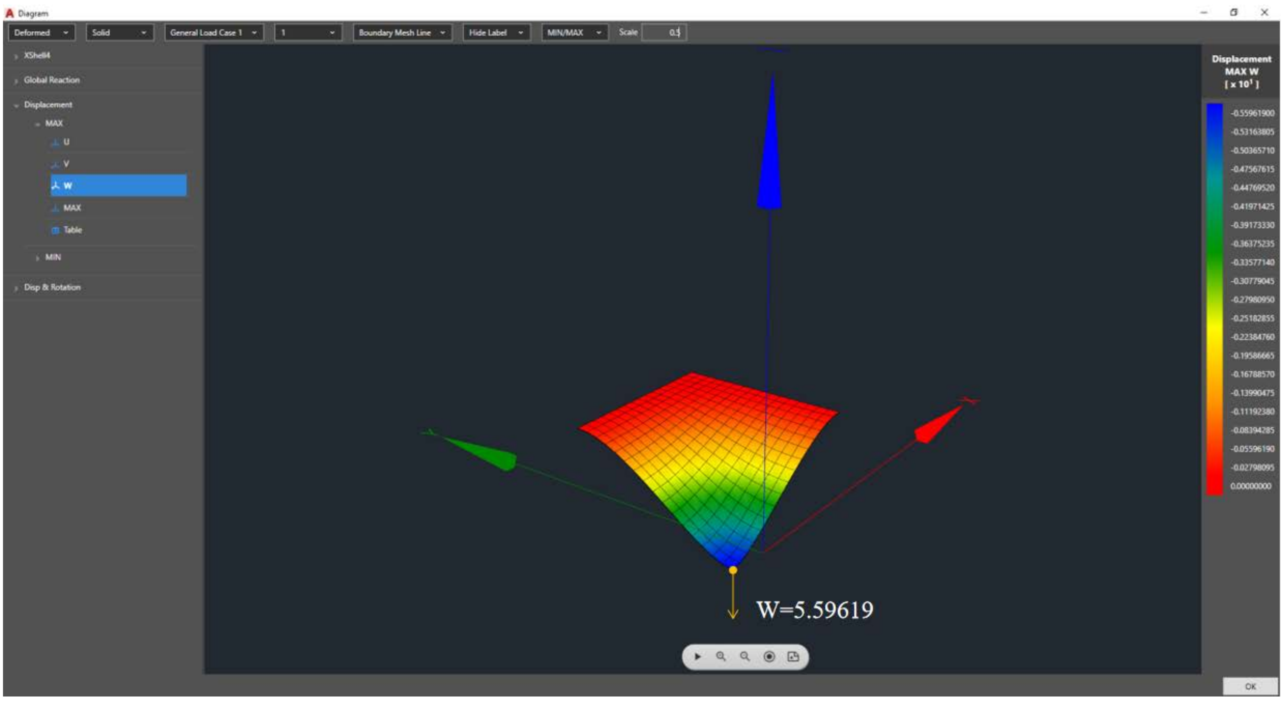


Fig.10.3 Deformation of clamped plate model with regular mesh in point load-W (16×16, 4ANS)

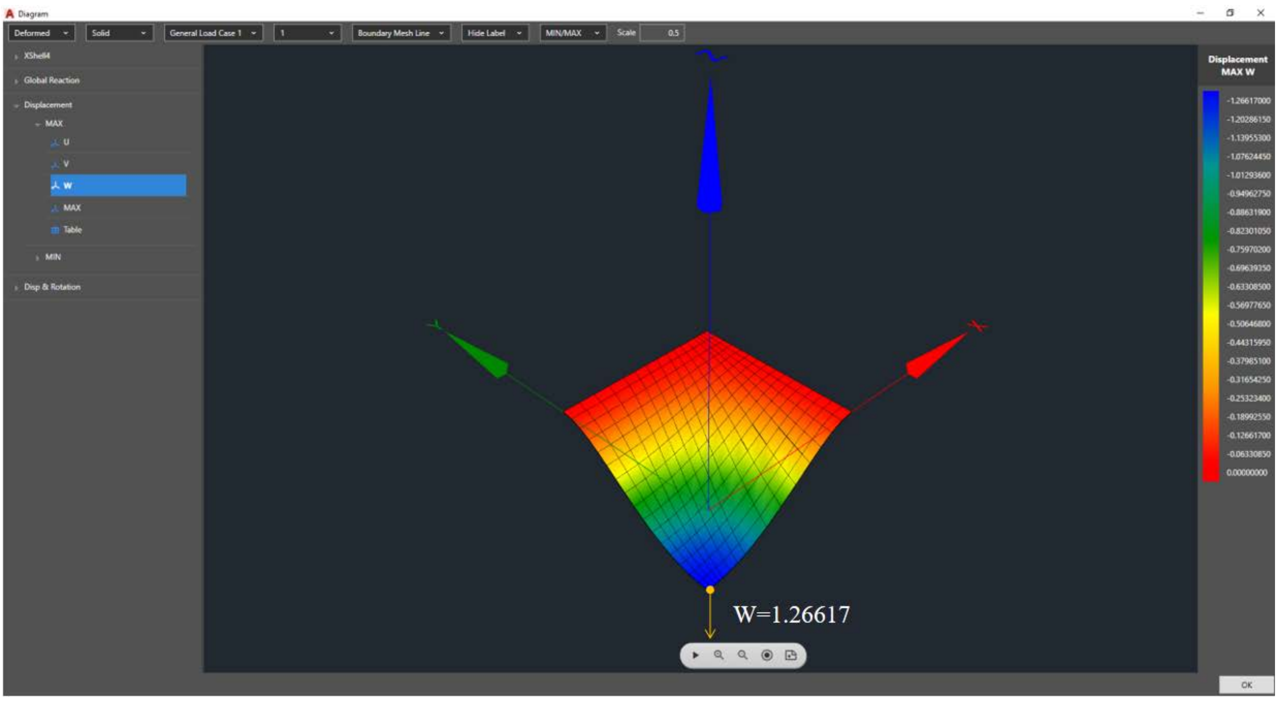
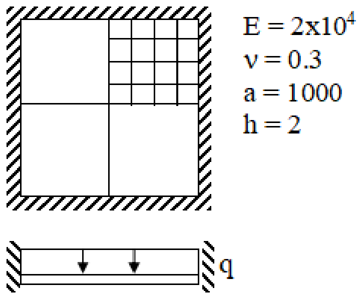


Fig.10.4 Deformation of clamped plate model with distorted mesh in uniform load-W (16×16, 4ANS)

Verification Example of X-SEA AutoCAD	No: Shell Element 011
Title: Square Clamped Plate Subjected to Uniform Pressure	
Problem Description	

The deflection of a square clamped plate subjected to a uniformly distributed increasing pressure is analyzed. Sixteen shell elements were used to model on quarter of the plate. The present XSHELL-4-ANS element matches with the analytical solution given by Timoshenko and Woinowsky-Krieger (1959).

a=1000; t=2; E=2×10^4; v=0.30; Mesh=n×n(1/4 sym model); Load: q=0.01;



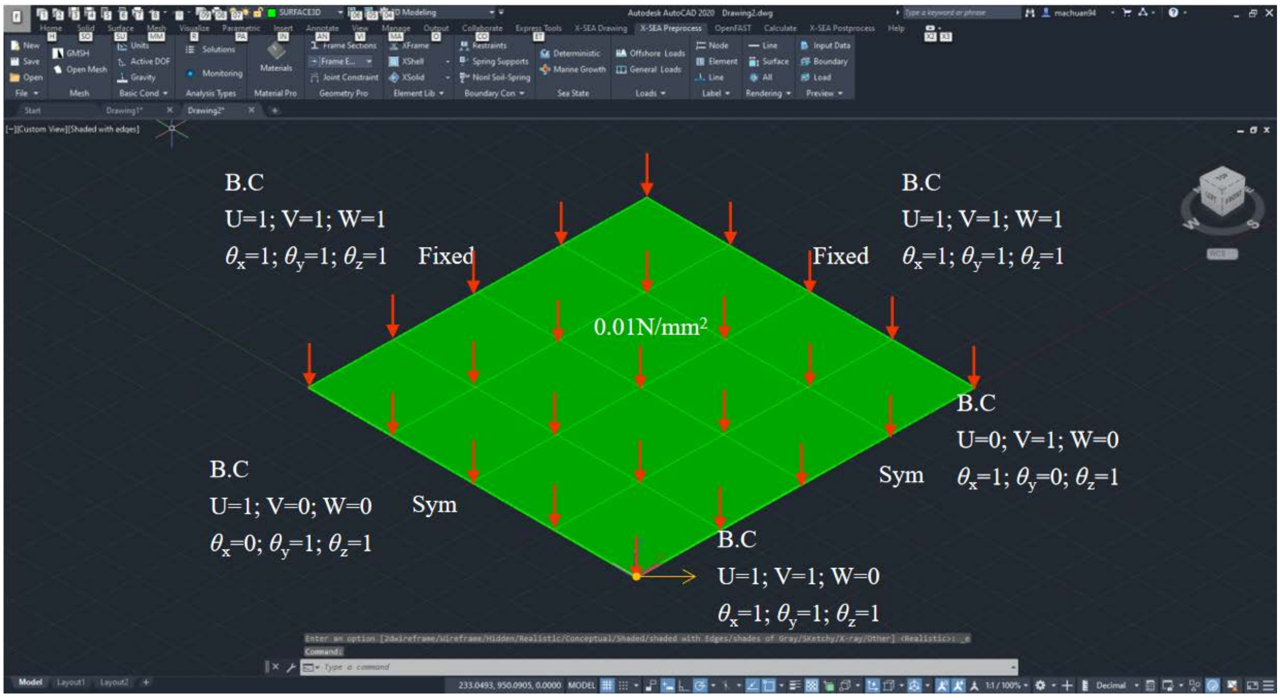


Fig. 11.1 Square clamped plate model and properties (4×4, 4ANS)

Results

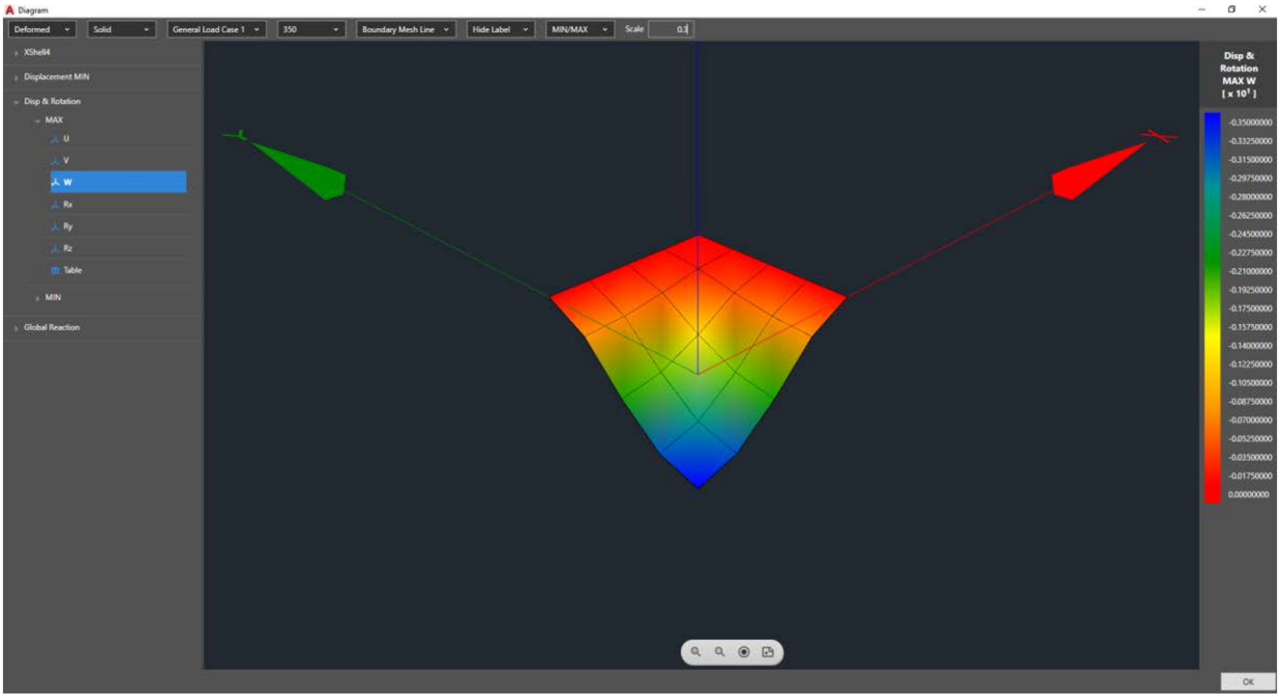


Fig.11.2 Deformation of clamped plate model in Z direction-W (4×4, 4ANS)

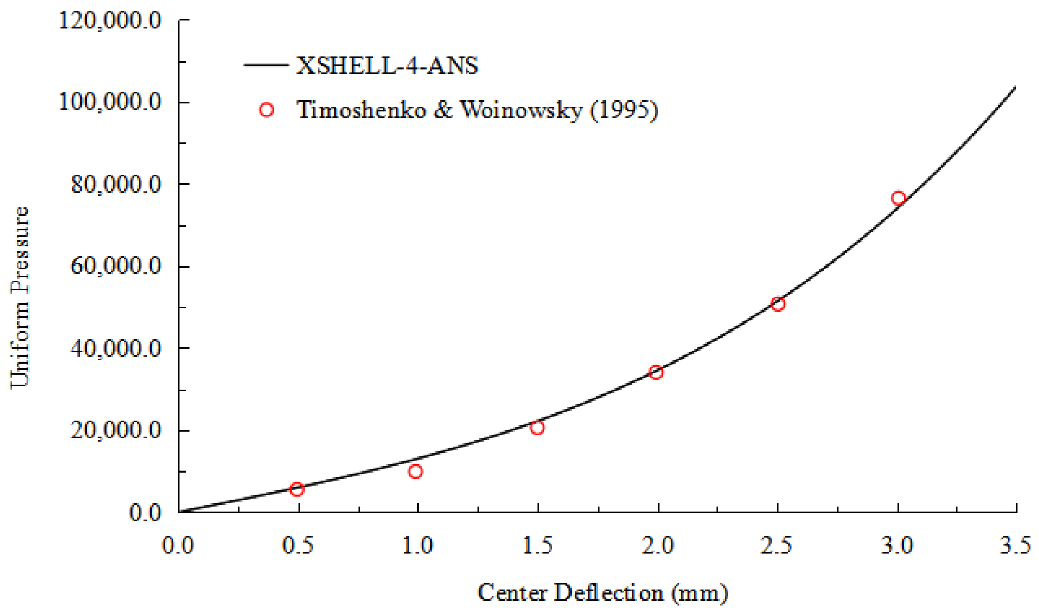


Fig.11.3 Load-Deflection curves for center displacement

Verification Example of X-SEA AutoCAD	No: Shell Element 012

Title: Hinged Cylindrical Shell

Problem Description

The snap through behavior of two cylindrical shells subjected to a point load at the center was analyzed. The cylindrical shell is simply supported along the longitudinal boundaries and unsupported along the curved edges. Only one quarter of the problem was modeled using an 8x8 mesh of each new element.

R=2.54m; L=0.508m; t=12.7mm or 6.35mm; E=3.10275×10^{9}N/m^2; ν=0.30; θ=0.1rad; Mesh=8×8 (1/4 sym model); Load: P=1N;

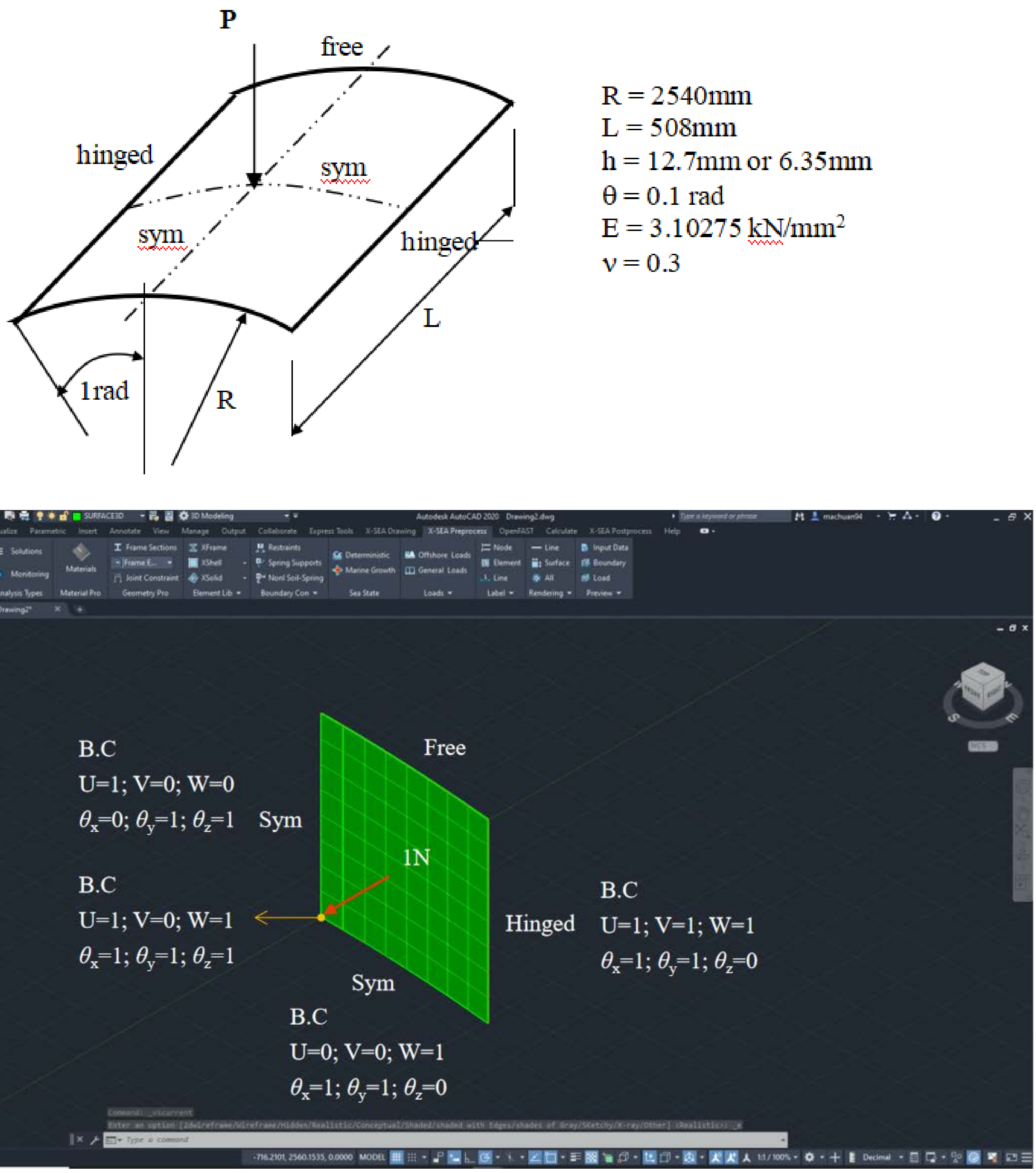


Fig. 12.1 Hinged cylindrical shell model & properties (8×8, 4ANS)

Results

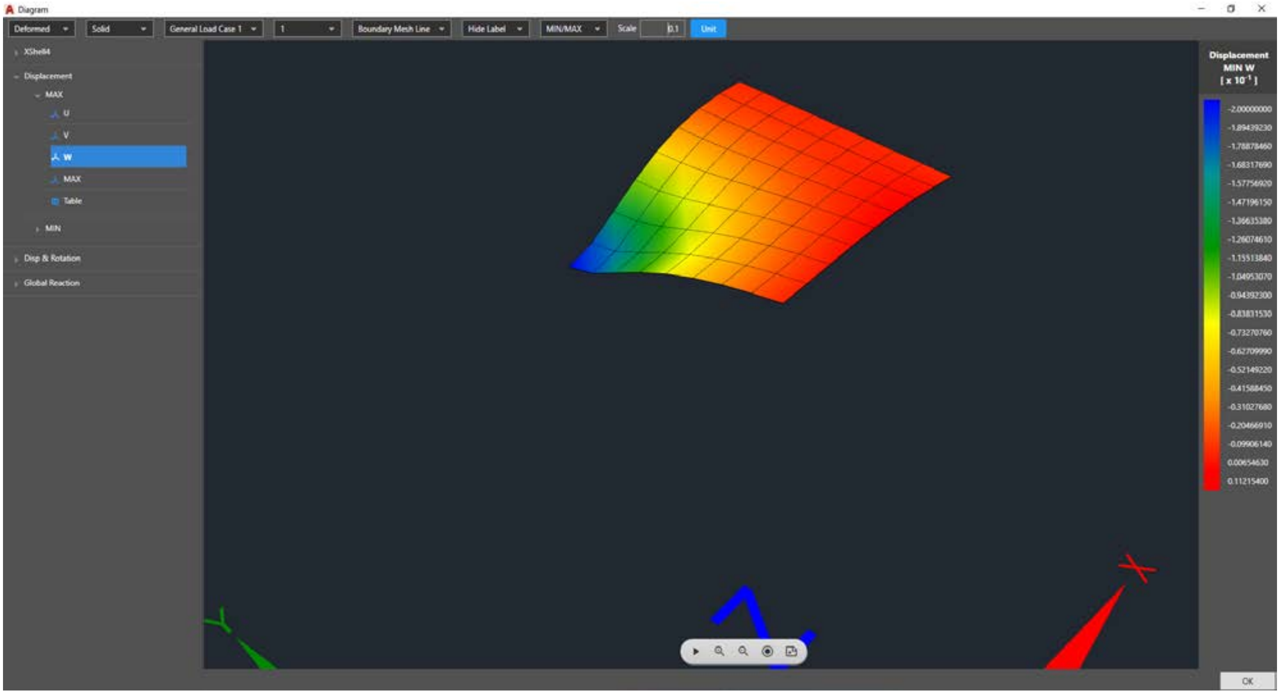


Fig.12.2 Deformation of hinged cylindrical shell model-W (8×8, 4ANS)

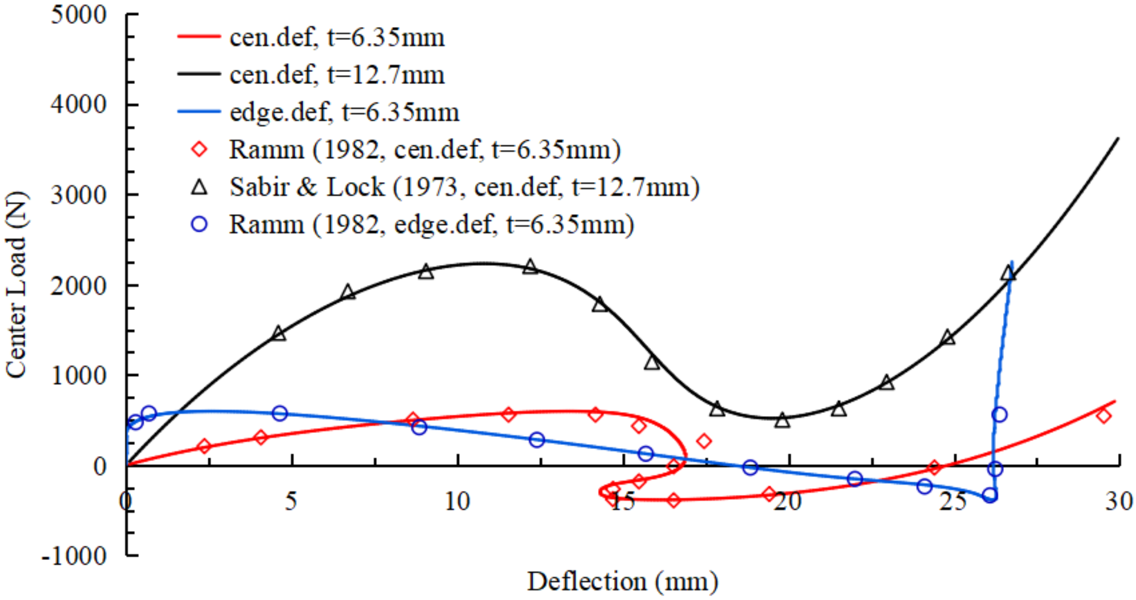


Fig.12.3 Load-Deflection Curves for Center Displacement

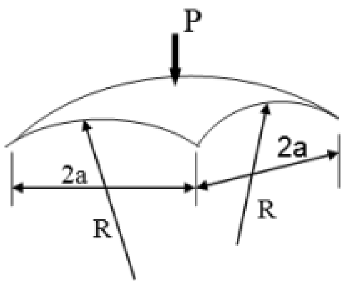
Verification Example of X-SEA AutoCAD	No: Shell Element 013

Title: Hinged Spherical Shell with Concentrated Load

Problem Description

A spherical shell with hinged edges and dimensions and material properties shown in Fig.13.1 is subjected to a point load at its crown. Using an 8x8 mesh of one quarter of the shell, the structure was analyzed for pre and post buckling response.

R=2540mm; a=784.9mm; h=99.45mm; E=68.95kN/mm^2; v=0.30; Mesh=8×8(1/4 sym model); Load: P=1N;



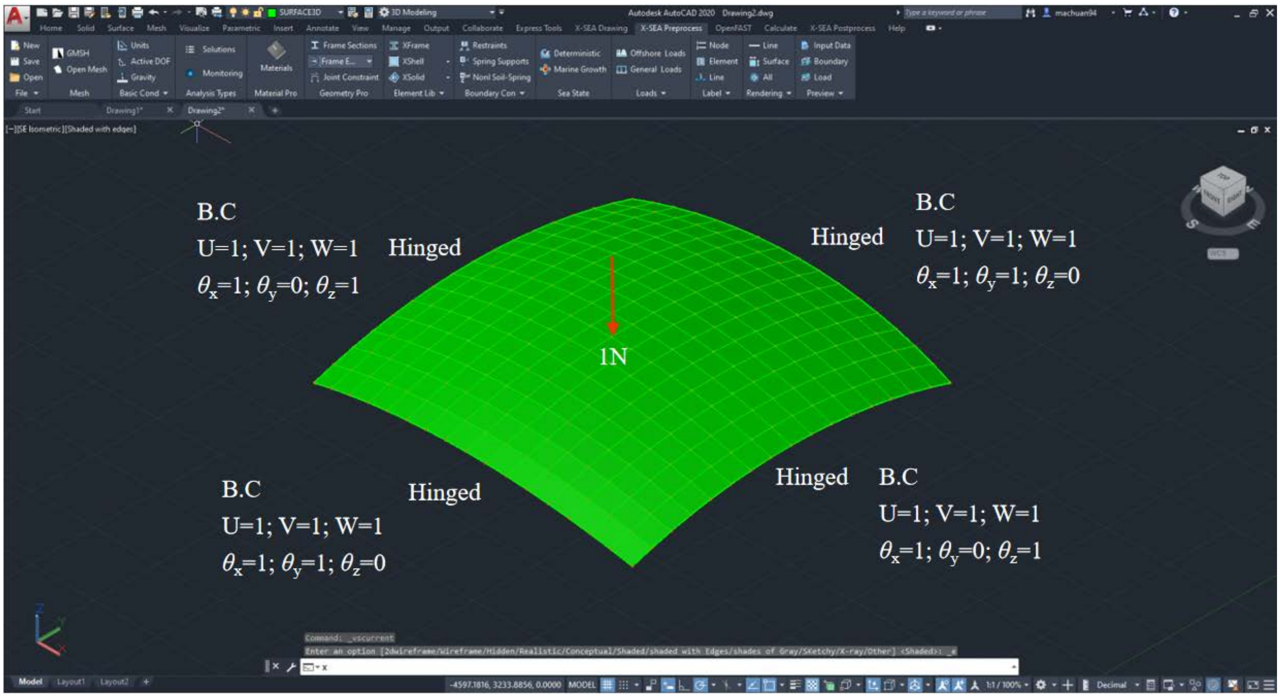


Fig. 13.1 Hinge spherical shell model and properties (16×16, 4ANS)

Results

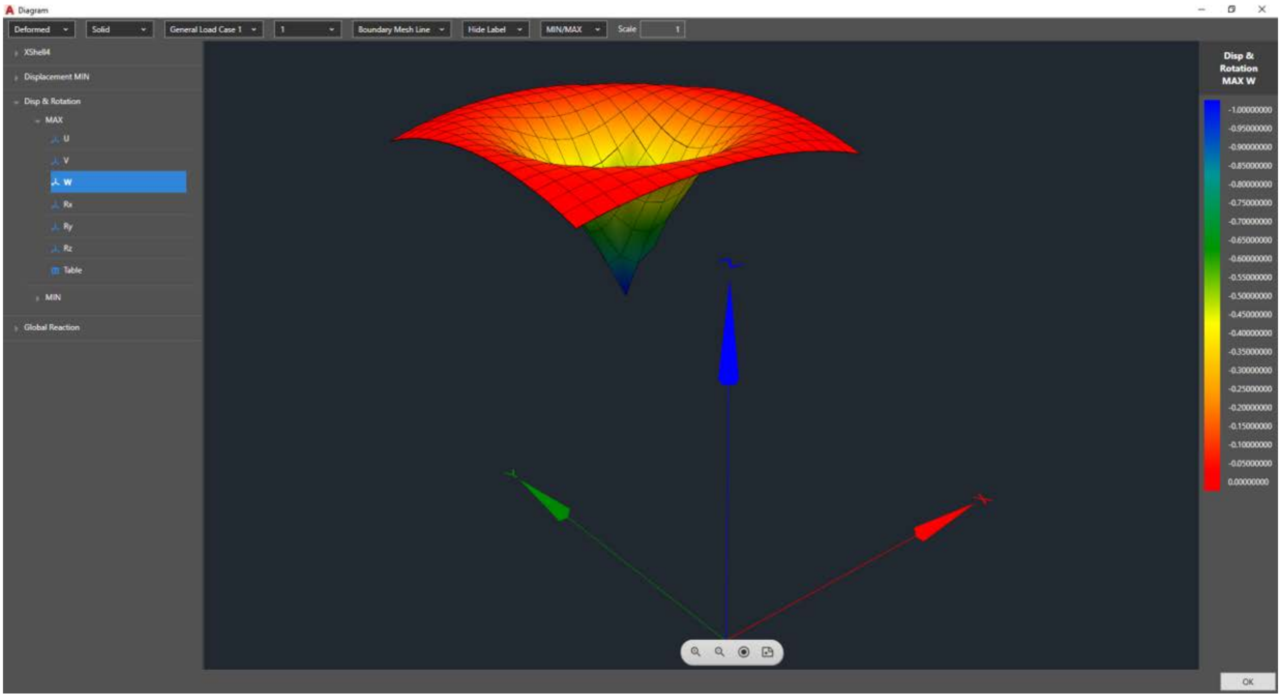


Fig.13.2 Deformation of hinge spherical shell model-W (16×16, 4ANS)

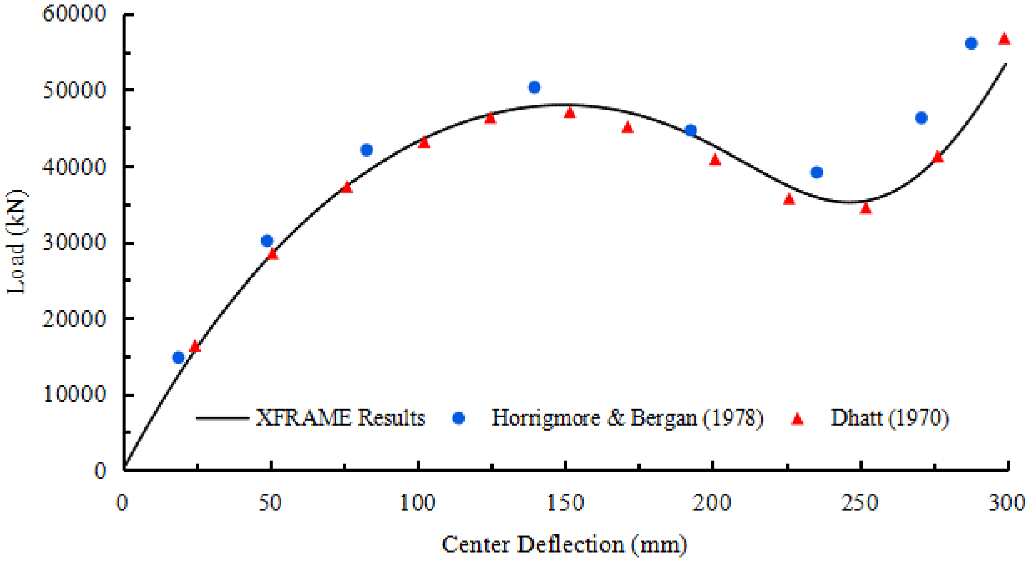


Fig.13.3 Load-Deflection curves for center displacement