AME 486

Project 9

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#1

- Based on the given material properties and inserted into the Excel sheet properly, the rest of the material properties were changed accordingly and properly by checking their equations of the excel sheet
- Material properties are:

D14

	A	B	C	D	E	F	G
1	E11	E22	v12	G12		v21	thickness
2	1.20E+07	1.00E+06	0.3	7.50E+05		2.50E-02	9.00E-03
3							
4	Q11	Q22	Q12	Q66			
5	1.21E+07	1.01E+06	3.02E+05	7.50E+05			
6							
7	U1	U2	U3	U4		U5	
8	5.36E+06	5.54E+06	1.19E+06	1.49E+06		1.94E+06	

#1

- **Constraints**
  - Maximum fiber strain should not exceed 1%
  - Material properties given should be used
- **Assumptions**
  - Presume a finite element model and requested section forces from Abaqus extracted the stress and bending resultants N & M

- **Problem Statement**: Come up with several combinations of N & M to come up with stacking sequences with the excel document

With no changes to the excel sheet except the material properties, we see with default N & M:

Shell Section Loads	
Nxx	247.00
Nyy	-3130.00
Nxy	130.00
Mxx	31.00
Myy	6.00
Mxy	-5.00

Loc Midplane	ACTIVE	Constraint	Theta	Failure Criteria Max Strain
1	1		0.00	1.065140958
2	1	0	75.00	0.851584527
3	1	0	-75.00	0.755748685
4	1	0	90.00	1.194570289
5	0	1	75.00	0

- The two plies that fail the max strain (1%) are the plies closest and farthest from the Loc Midplane

Using 4 active plies from the midplane, meaning there is a total 8 plies, we can for the default N & M, we see:

- 2 plies that are under the 1% max strain
- 2 plies that are over the 1% max strain

#1

First Combination of N & M

- Changing the values for N & M, it showed that changing the values for Nxx and Nyy solved our problem of max strain for those 2 plies as shown:

Shell Section Loads	
Nxx	100.00
Nyy	-2000.00
Nxy	130.00
Mxx	31.00
Myy	6.00
Mxy	-5.00

Loc Midplane	ACTIVE	Constraint	Theta	Failure Criteria Max Strain
1	1		0.00	0.900995296
2	1	0	75.00	0.513487588
3	1	0	-75.00	0.417651746
4	1	0	90.00	0.820413955
5	0	1	75.00	0

Combination #1

- It seems as if having a smaller negative N in the yy direction and a smaller positive N in the xx direction solved our problem of having too much strain in the closest and farthest plies from the midplane location

- From multiple iterations it was found that increasing the Nyy to have a larger, negative value would introduce more strain towards all three plies farthest from the Loc Midplane (2, 3, 4)

Second Combination of N & M

- Building off Combination #1, and not changing the value of Nxx and Nyy, we can see the effect on strain the other resultant forces and moments have on it:

Shell Section Loads	
Nxx	100.00
Nyy	-2000.00
Nxy	500.00
Mxx	31.00
Myy	6.00
Mxy	-5.00

				Failure Criteria
Loc Midplane	ACTIVE	Constraint	Theta	Max Strain
1	1		0.00	0.900995296
2	1	0	75.00	0.268001973
3	1	0	-75.00	0.663137361
4	1	0	90.00	0.820413955
5	0	1	75.00	0

Combination #2

- From only changing the resultant force Nxy, we can see only the 2 middle plies (2, 3) between the closest and farthest plane from Loc Midplane (1 , 4) were affected
  - A greater, positive Nxy value decreased the strain on plies 2 and 3 significantly
    - This may be due to the +75, - 75 plies, their orientation, that is better at absorbing shear, and since the laminate is symmetric, no coupling between bending and extension exists

Third Combination of N & M

- Building off Combination #3, and not changing the value of Nxx, Nyy, Nxy, we can see the effect on strain the other resultant moment (Mxy) have on it:

Shell Section Loads	
Nxx	100.00
Nyy	-2000.00
Nxy	500.00
Mxx	31.00
Myy	6.00
Mxy	-15.00

				Failure Criteria
Loc Midplane	ACTIVE	Constraint	Theta	Max Strain
1	1		0.00	0.889855075
2	1	0	75.00	0.525331052
3	1	0	-75.00	0.347306309
4	1	0	90.00	0.899632327
5	0	1	75.00	0

Combination #3

- From only changing the resultant moment Mxy, we can see all the strains for each ply were altered
  - The closest ply to the midplane location (1) being the least affected by the change in Mxy
  - However, plies (2, 3, 4) showed massive changes in their strain but still within the maximum strain of 1%
- This behavior is to be expected as applying a more negative Mxy WILL show higher strain at the outermost plies because:
  - The bending moments like Mxy create curvatures, and curvature-induced strain incrase with distance from the midplane

Fourth Combination of N & M

- Building off Combination #4, and not changing the value of Nxx, Nyy, Nxy, and Mxy we can see the effect on strain the other resultant moments (Mxx & Myy) have on it:

Shell Section Loads	
Nxx	100.00
Nyy	-2000.00
Nxy	500.00
Mxx	20.00
Myy	20.00
Mxy	-15.00

				Failure Criteria
Loc Midplane	ACTIVE	Constraint	Theta	Max Strain
1	1		0.00	0.612177029
2	1	0	75.00	0.441235465
3	1	0	-75.00	0.216120574
4	1	0	90.00	0.5564989
5	0	1	75.00	0

Combination #4

- From changing the resultant moments Mxx and Myy, we can see all the strains for each ply were altered to having the same positive moment:
  - Although still within the constaint of having a maximum strain of 1%, all the plies were affected by the changes as plies (1 and 4) showed a decrease in strain but plies (2 and 3) showed an increase in strain which is be expected from ± 75 plies as they can handle more strain to relieve the other plies from too much strain referring to some load distribution happening

Fourth Combination of N & M

- Building off Combination #4 more, and making more plies active with their corresponding ply angles (theta) we can see from the 12 plies:

Shell Section Loads	
Nxx	100.00
Nyy	-2000.00
Nxy	500.00
Mxx	20.00
Myy	20.00
Mxy	-15.00

				Failure Criteria
Loc Midplane	ACTIVE	Constraint	Theta	Max Strain
1	1		0.00	0.155319699
2	1	0	75.00	0.25411732
3	1	0	-75.00	0.300126381
4	1	0	90.00	0.31299459
5	1	0	75.00	0.257324768
6	1	0	-75.00	0.288323737
7	1	0	88.59	0.312562541
8	1	0	-88.59	0.315151644
9	1	0	0.00	0.370269439
10	1	0	75.00	0.262670515
11	1	0	-75.00	0.268652662
12	1	0	90.00	0.316144215
13	0	1	75.00	0

- From this change, as we expected:
  - There would smaller strains at the original 4 plies from the midplane location as there are more plies for load distribution
  - Therefore, sharing the strain and bending from the resultant forces and moments across all 24 plies

#2

Module 5 Abaqus

- My results will look different than video but, numerical data should remain the same
  - Using 22 plies for model 2
  - Using thickness of 0.009

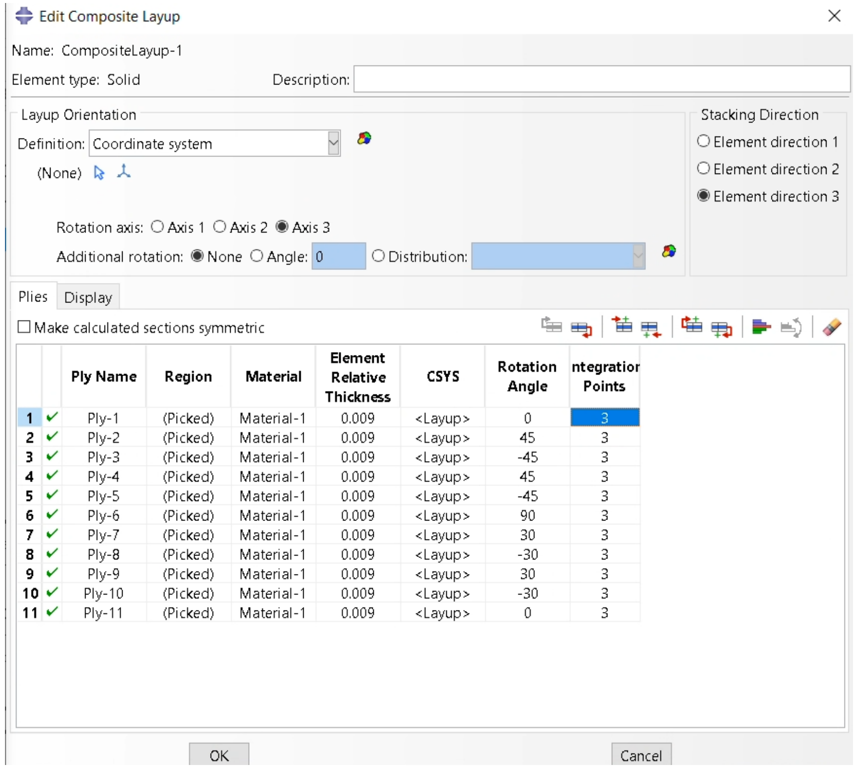
Laminate stacking sequence $[0/(+45/-45)_2/90/(+30/-30)_2/0]_s$; cured ply thickness is 0.009 inch

Material Name	E11	E22	E33	v12	v13	v23	G12	G13	G23
AS4/8552 Unidirectional	19,090,000 psi	1,340,000 psi	500,000 psi	0.30	0.40	0.40	700,000 psi	420,000 psi	420,000 psi

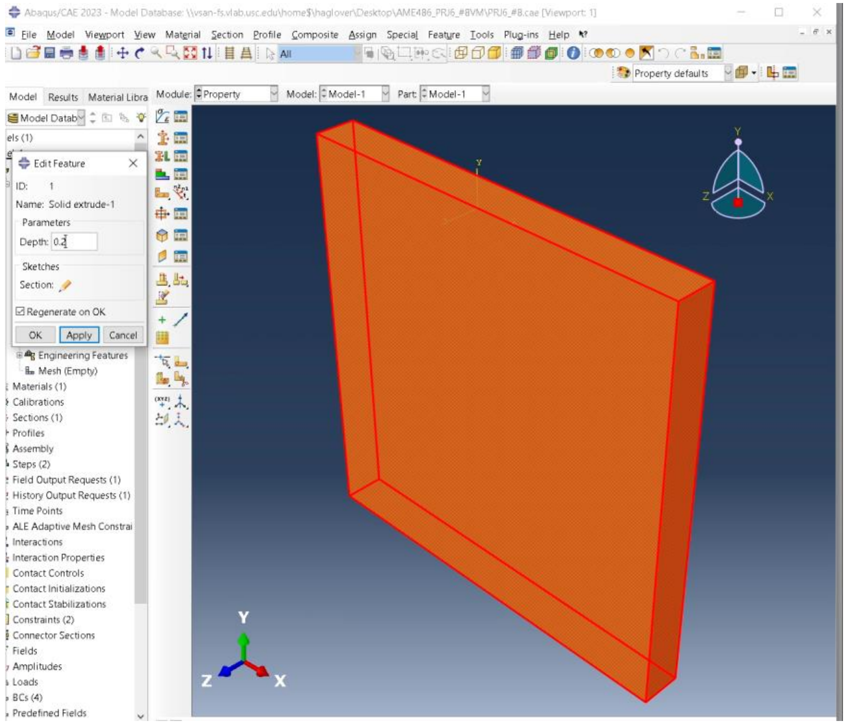
#2

Module 5 Abaqus

- Model 1
- Used 11 plies, with 0.009" thickness
- Setup is shown below



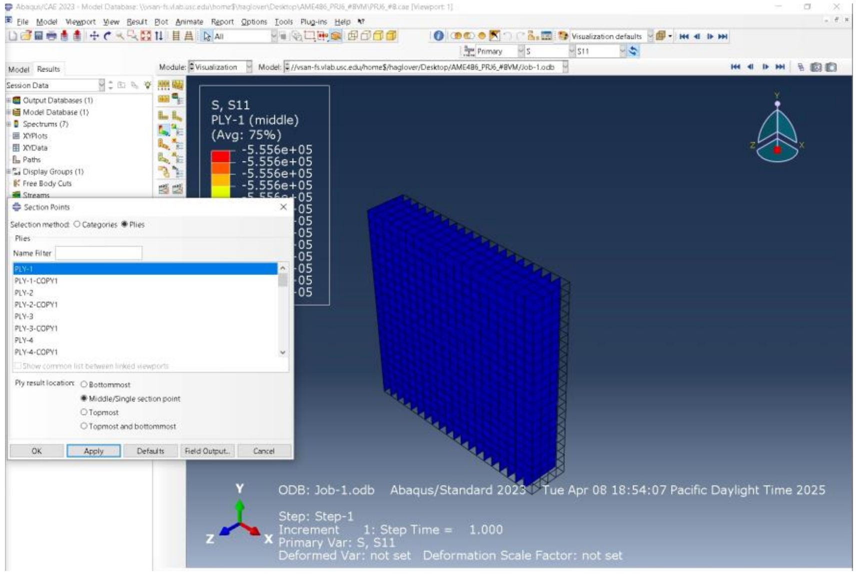
	Ply Name	Region	Material	Element Relative Thickness	CSYS	Rotation Angle	ntegratior Points
1	Ply-1	(Picked)	Material-1	0.009	<Layup>	0	3
2	Ply-2	(Picked)	Material-1	0.009	<Layup>	45	3
3	Ply-3	(Picked)	Material-1	0.009	<Layup>	-45	3
4	Ply-4	(Picked)	Material-1	0.009	<Layup>	45	3
5	Ply-5	(Picked)	Material-1	0.009	<Layup>	-45	3
6	Ply-6	(Picked)	Material-1	0.009	<Layup>	90	3
7	Ply-7	(Picked)	Material-1	0.009	<Layup>	30	3
8	Ply-8	(Picked)	Material-1	0.009	<Layup>	-30	3
9	Ply-9	(Picked)	Material-1	0.009	<Layup>	30	3
10	Ply-10	(Picked)	Material-1	0.009	<Layup>	-30	3
11	Ply-11	(Picked)	Material-1	0.009	<Layup>	0	3

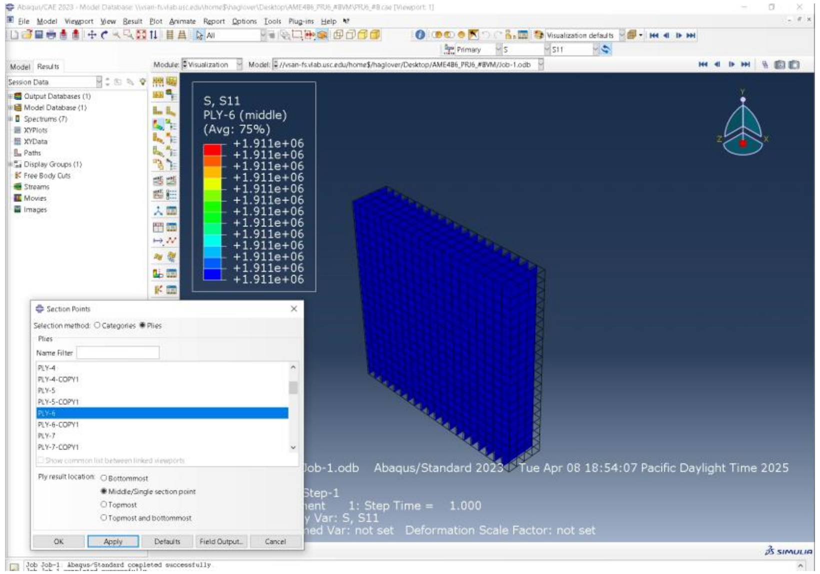


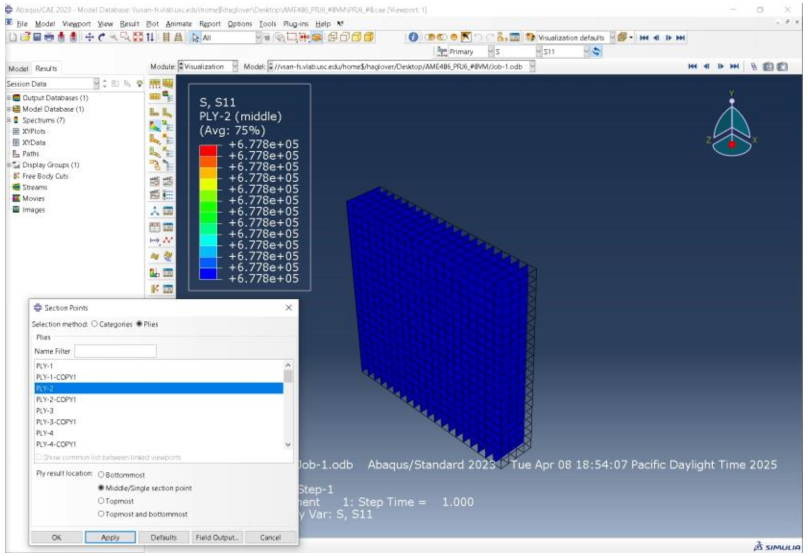
#2

Module 5 Abaqus

- Model 1 – Results (S11)
    - Ply-1 = -5.556E05 (Matches online data)
    - Ply-2 = 6.78E05 (Matches online data)
    - Ply-3 and 5 = Same
    - Ply-6 (90°) = 1.911E06 (Matches online data)



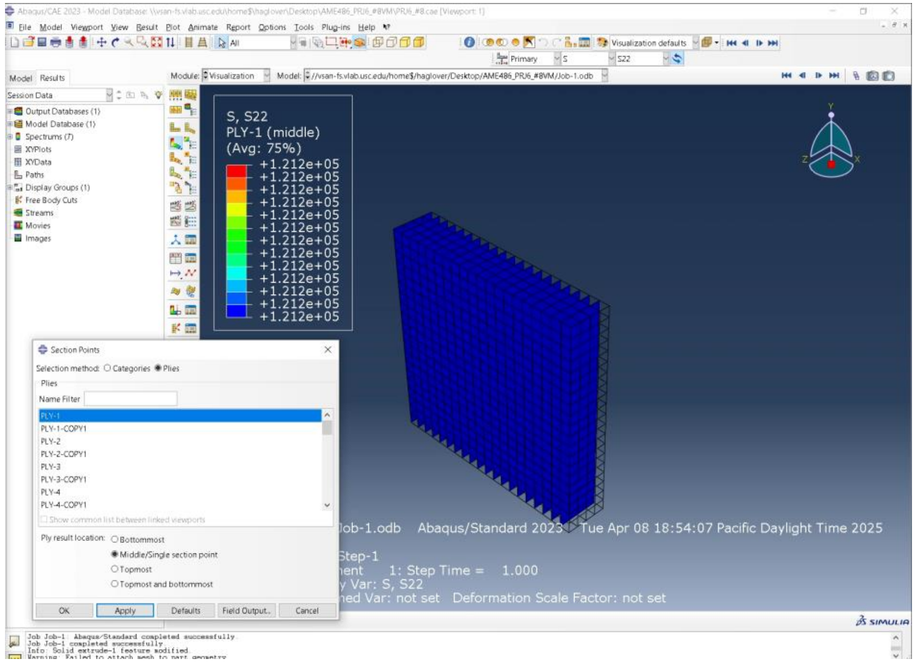


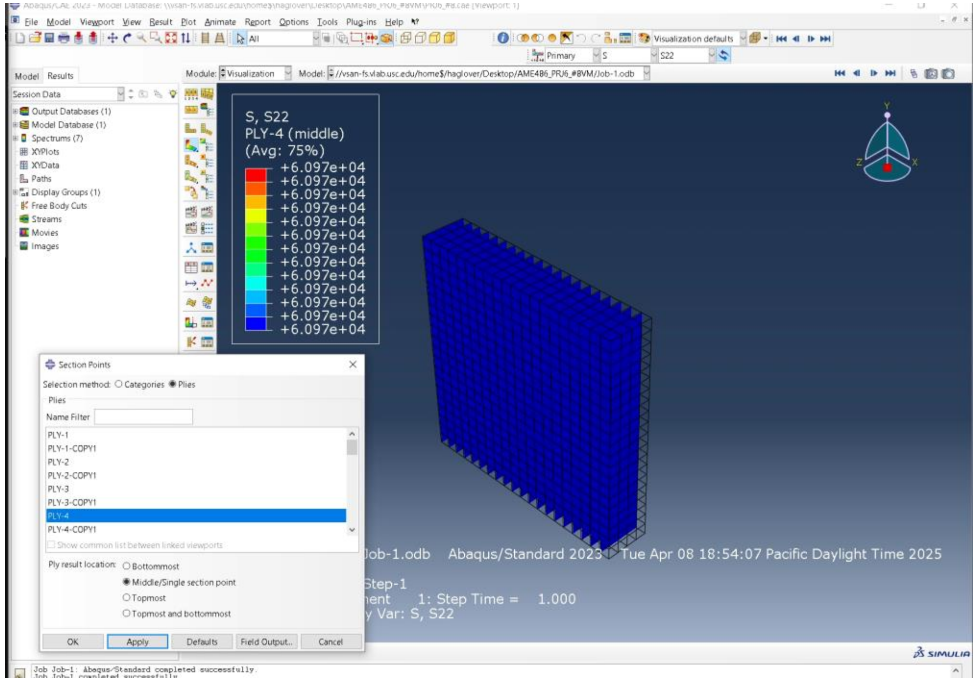


#2

Module 5 Abaqus

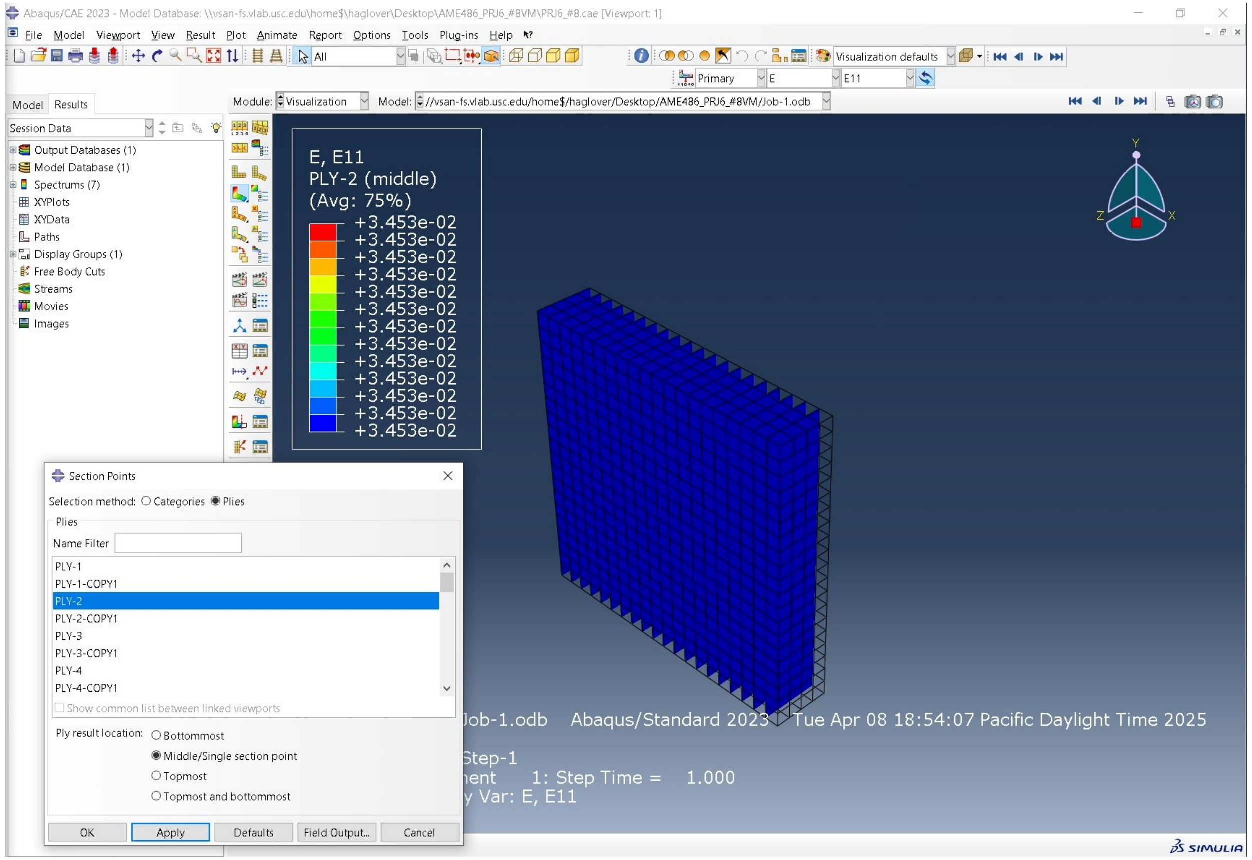
- Model 1 – Results (S22)
  - S22 data also matches up with online results
  - Ply-1 = 1.212E04 (Matches online data)
  - Ply-4 = 6.097E05 (Matches online data)





#2 Module 5 Abaqus

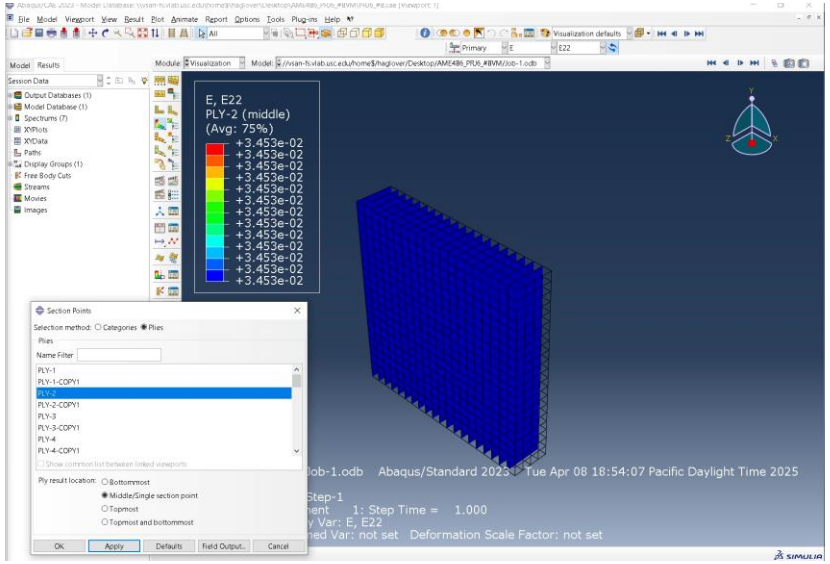
- Model 1 – Results (E11)
  - E11 data also matches up with online results
  - Ply-2 = 3.435E02 (Matches online data)

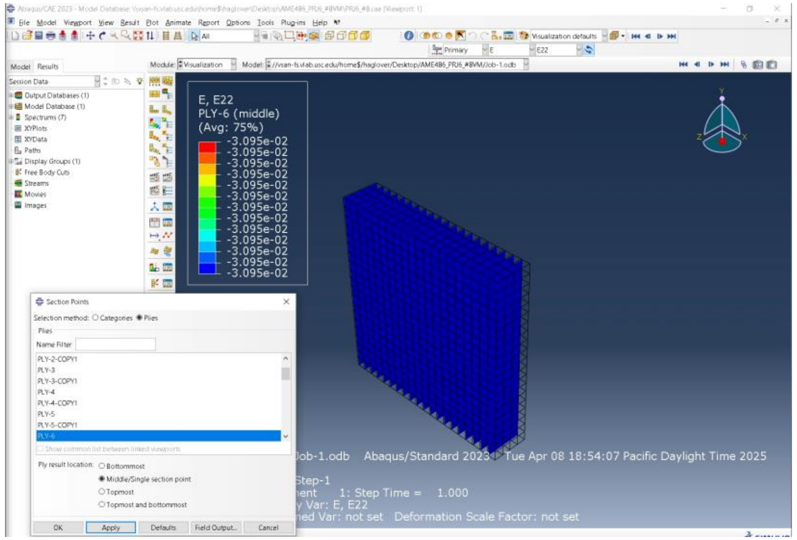


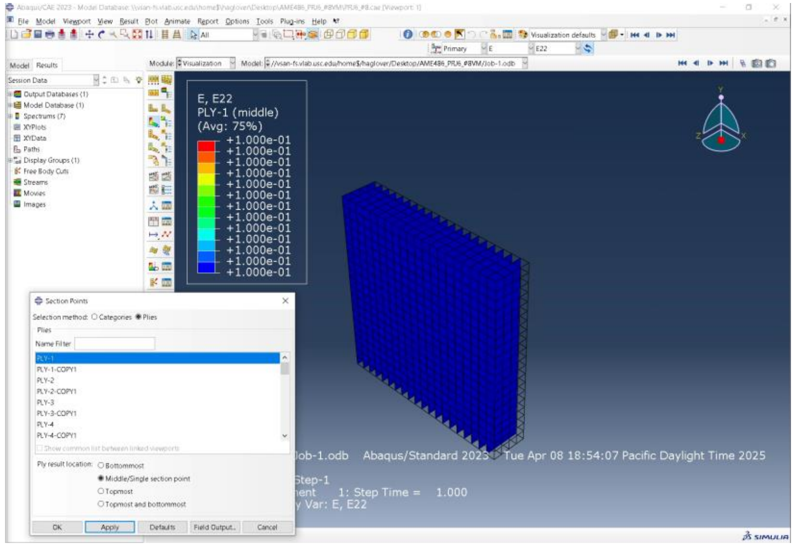
#2

Module 5 Abaqus

- Model 1 – Results (E22)
  - E22 data also matches up with online results
  - Ply-1 and Ply-11 = 3.435E02 (Matches online data)
    - Makes sense both 0 degrees
  - Ply-2 = 3.453E-02
  - Ply-6 = -3.095E-02

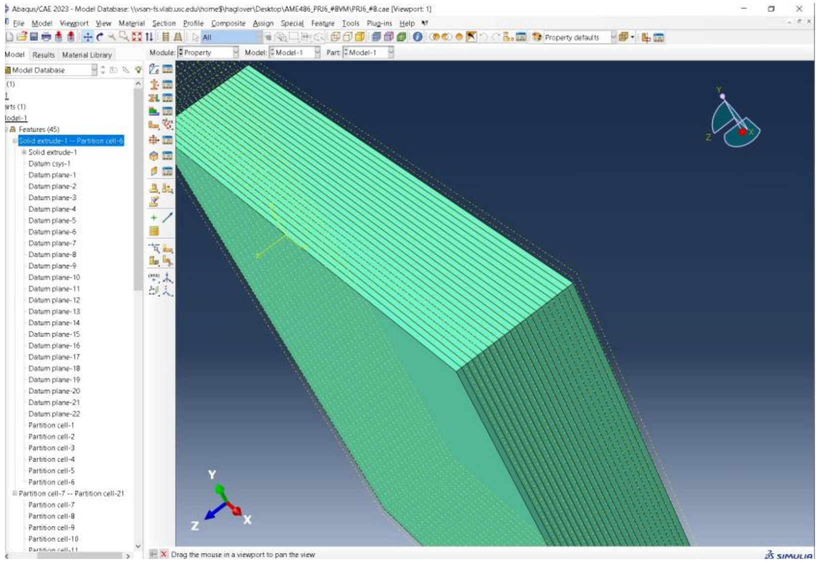


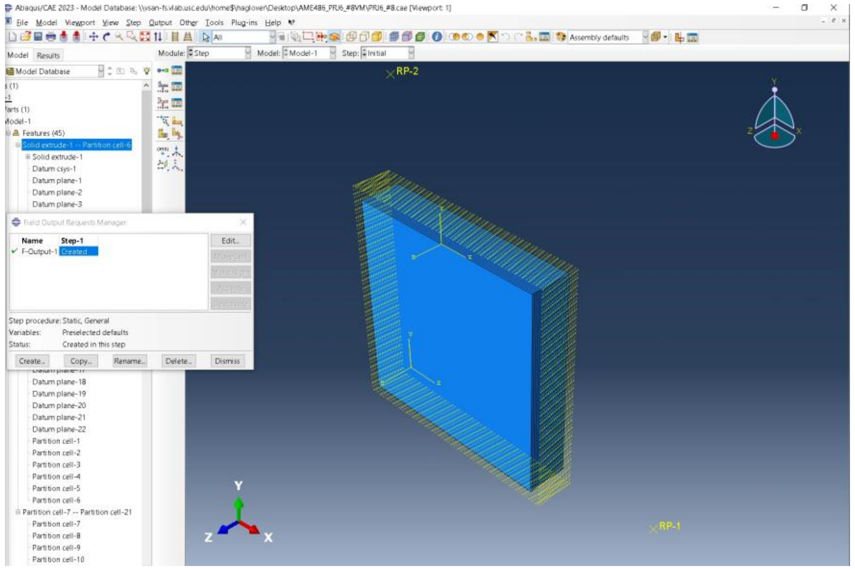




Module 5 Abaqus

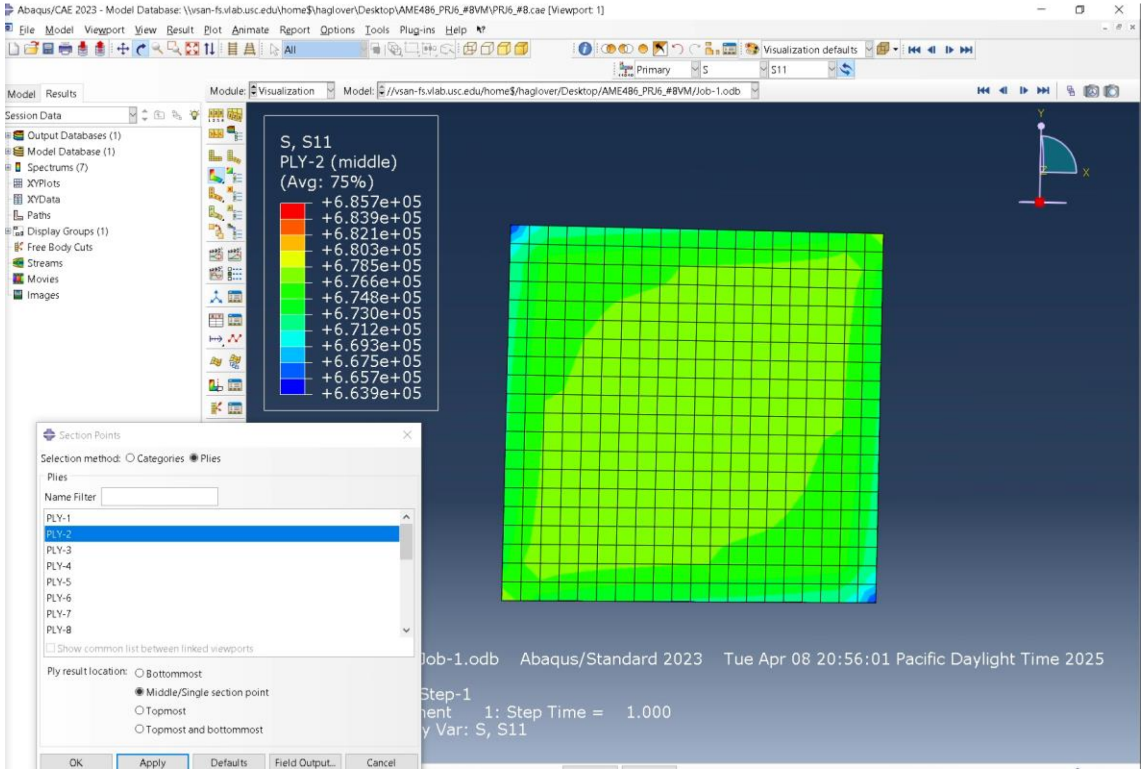
- Model 2 – Setup
- 22 plies are cut using datum planes

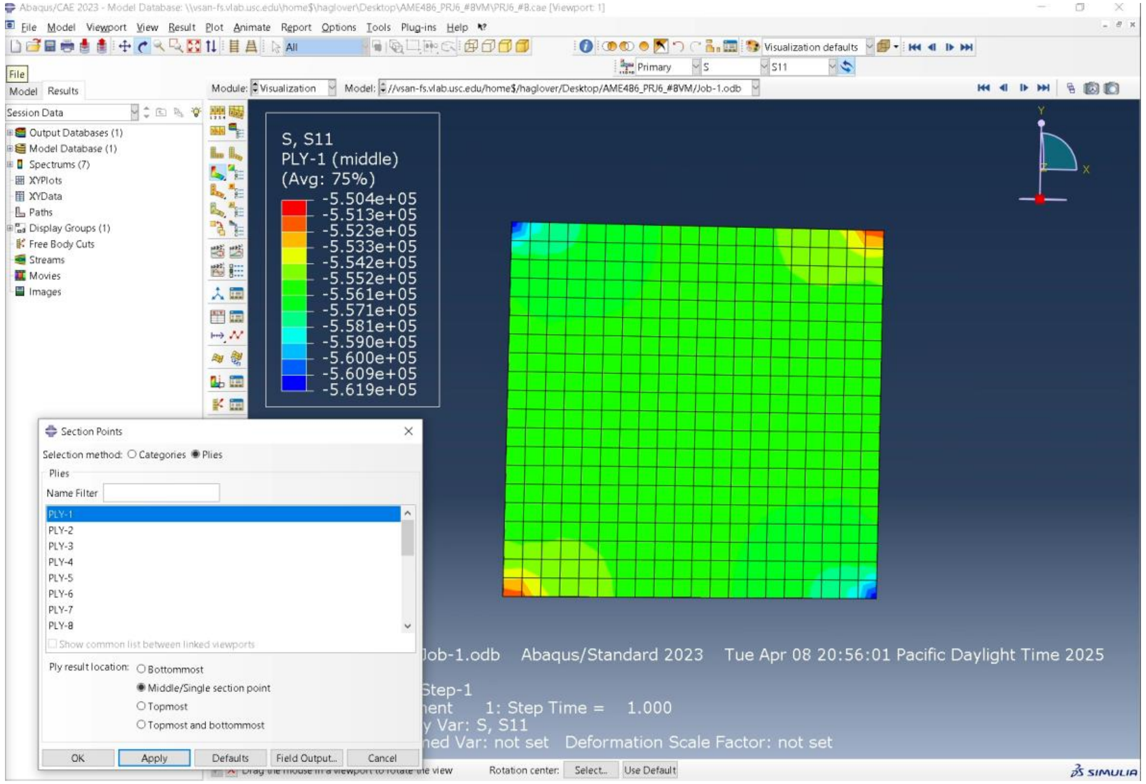




Module 5 Abaqus

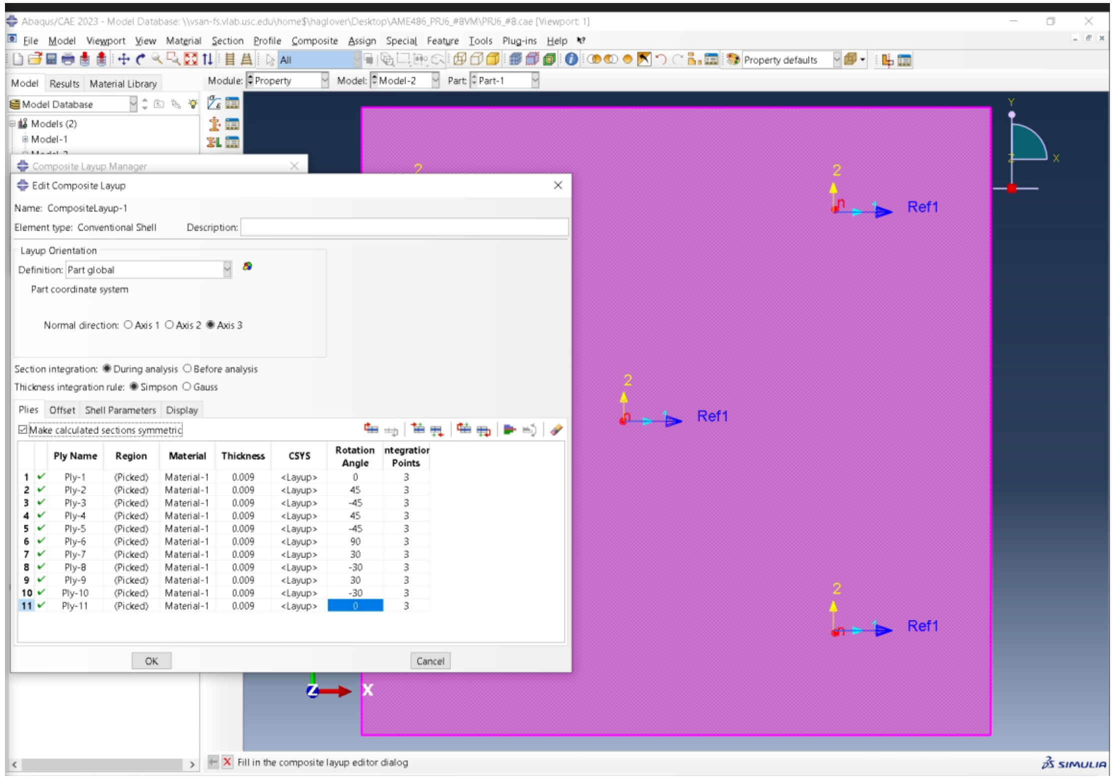
- Model 2 – Results
- Ply-2 = 6.78E05 (Matches model 1 data)
- Ply-1 = -5.556E05 (Matches model 1 data)





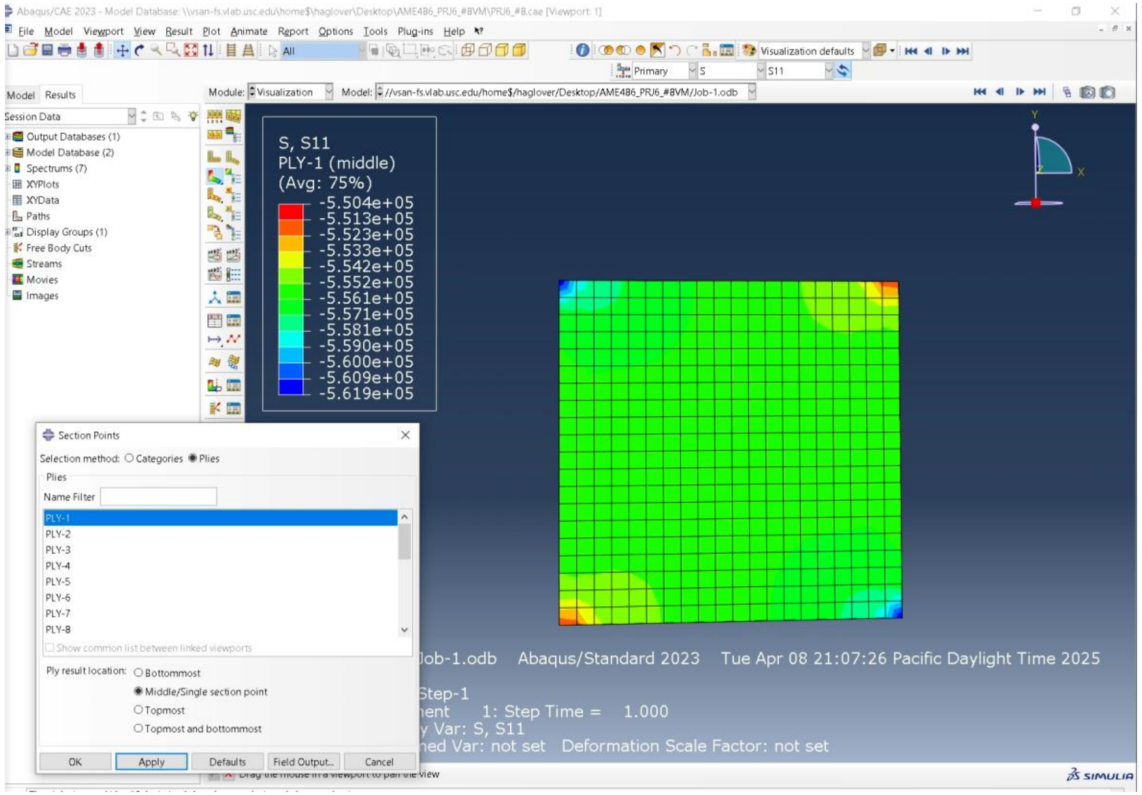
Module 5 Abaqus

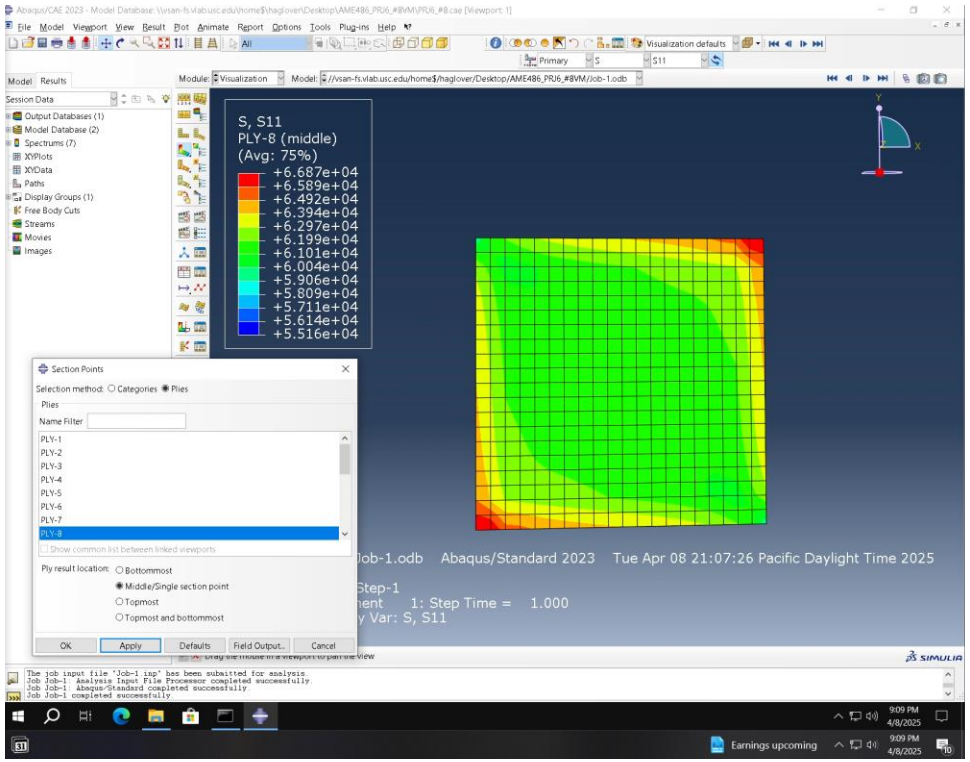
- Model 3 – setup
- Conventional shell setup
- 11 total ply’s - made symmetric



Module 5 Abaqus

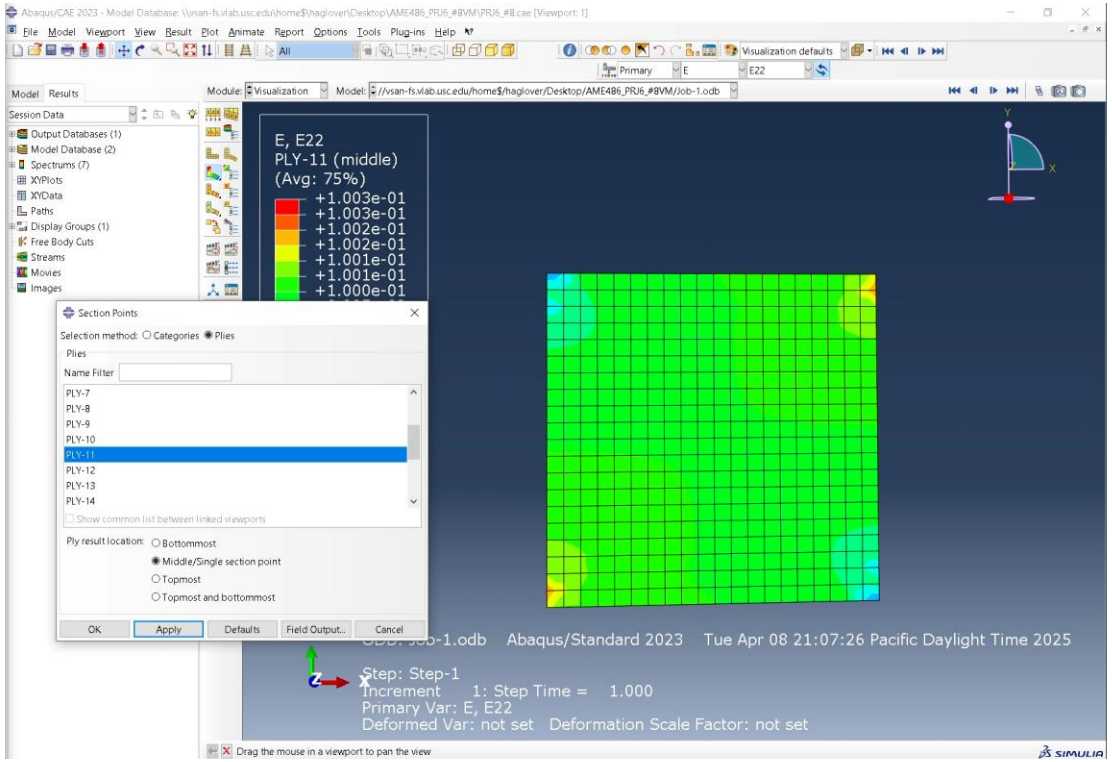
- Model 3 – (S11)
- Ply-1 = -5.561E05 (Matches online data and other models)
- Ply-8 = 6.101E04 (Matches other models)

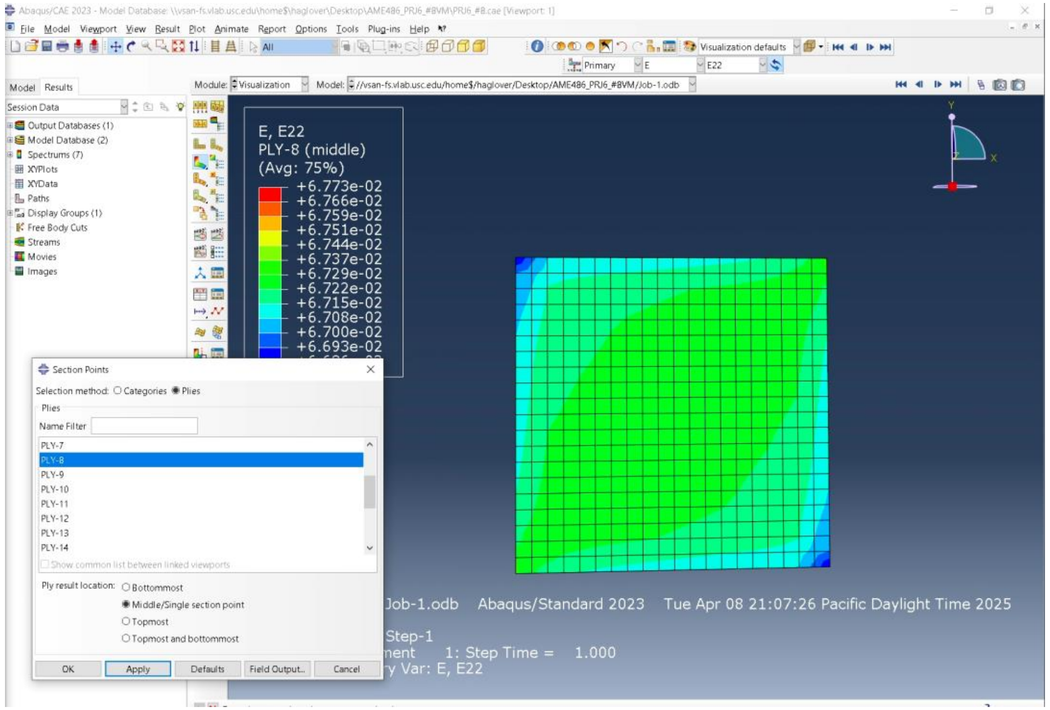




Module 5 Abaqus

- Model 3 – (E22)
- Ply-1 and 11 = 1.003E-01
- Ply-8 = 6.722E-03
    - slightly higher than expected, but matches regardless

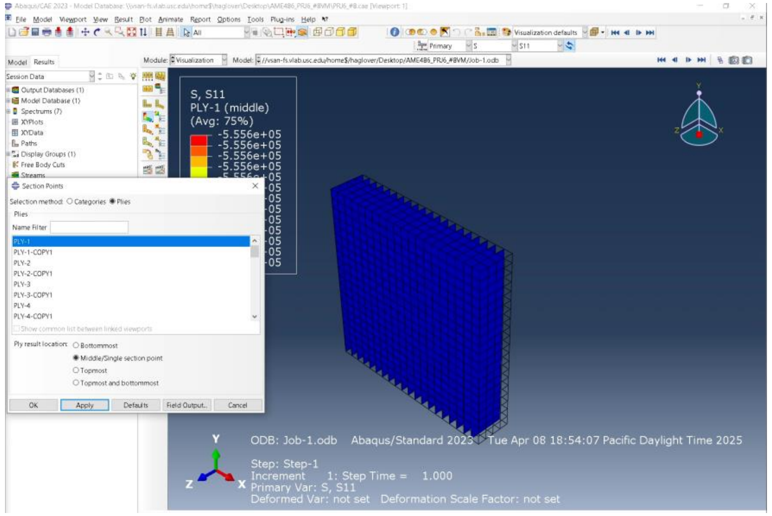




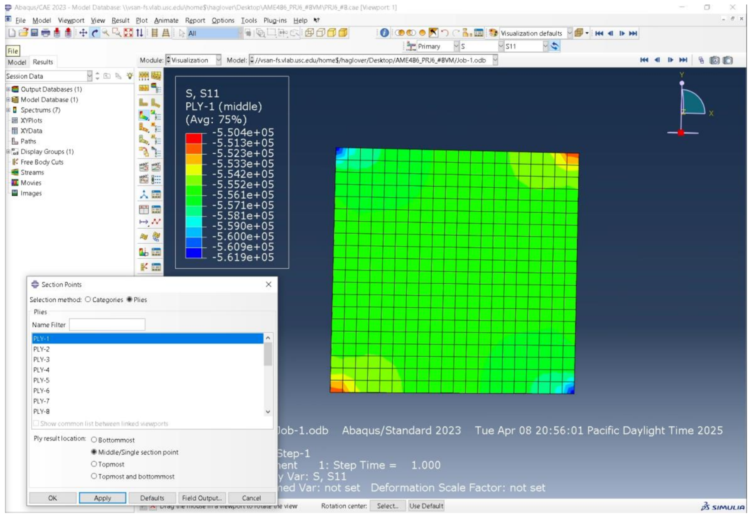
#2

Module 5 Abaqus

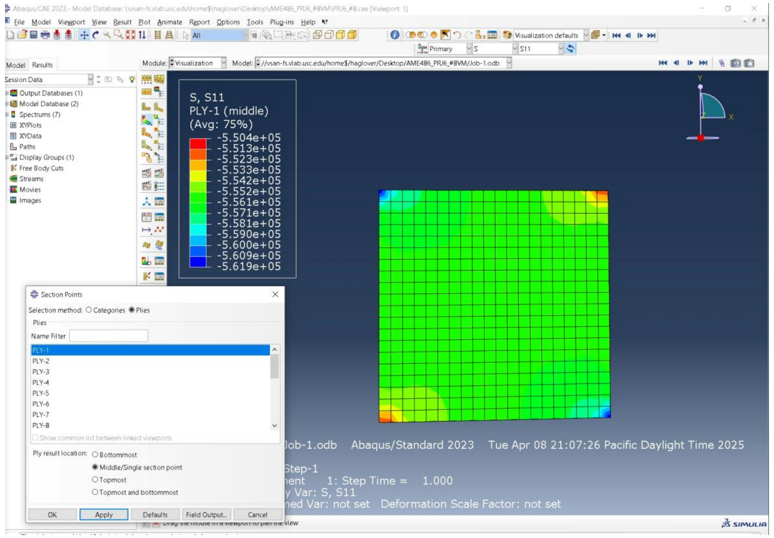
- Conclusion
- All three Models (1,2,3) match up with each other
    - Shown below in three images
- Means that all three methods are accurate ways to model a composite layup
- (S11) Ply-1 = -5.556E05



One Element though thickness – Model 1



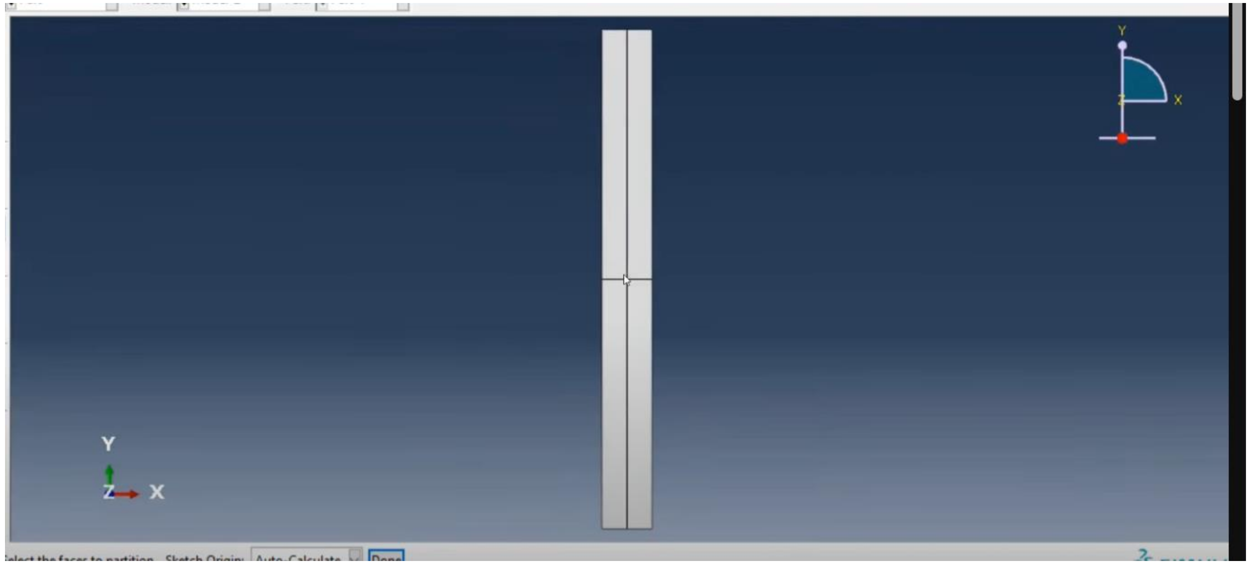
Stacking sequence method– Model 2

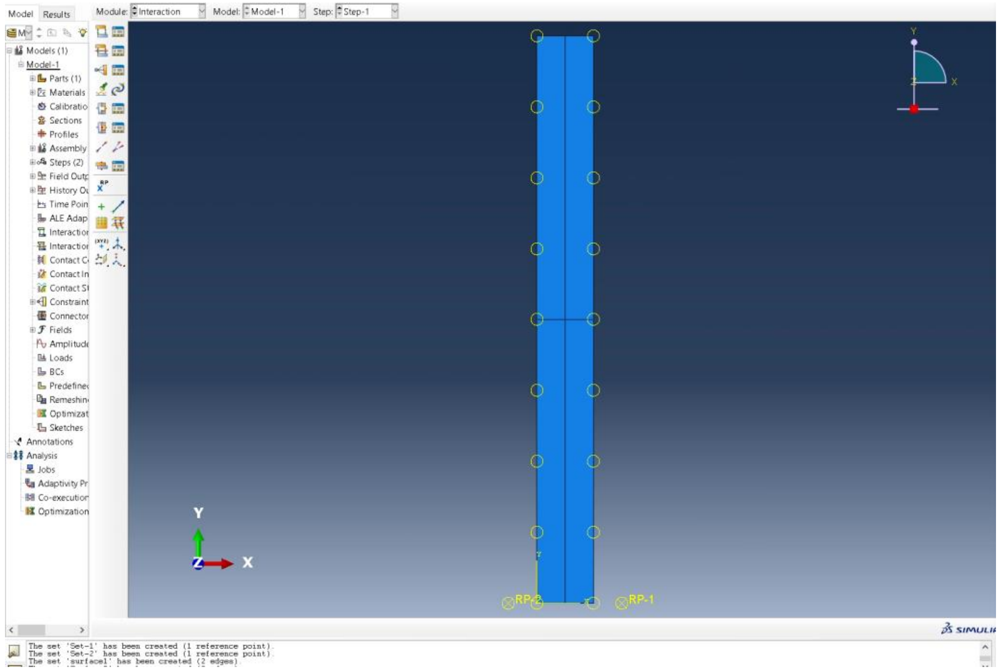


Shell method – Model 3

Module 6 Abaqus

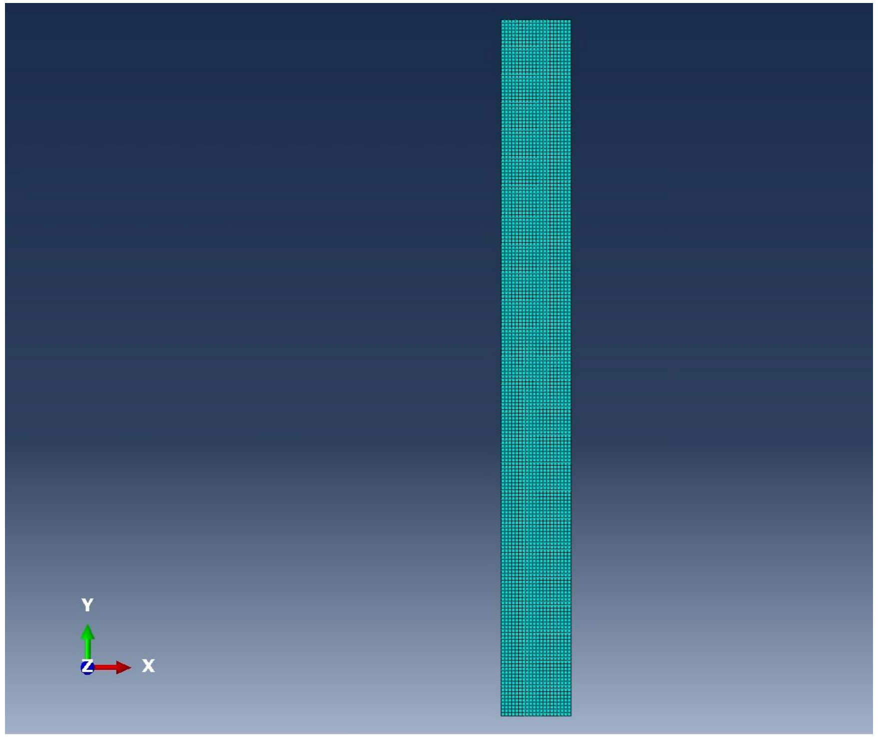
- Track reference midplane

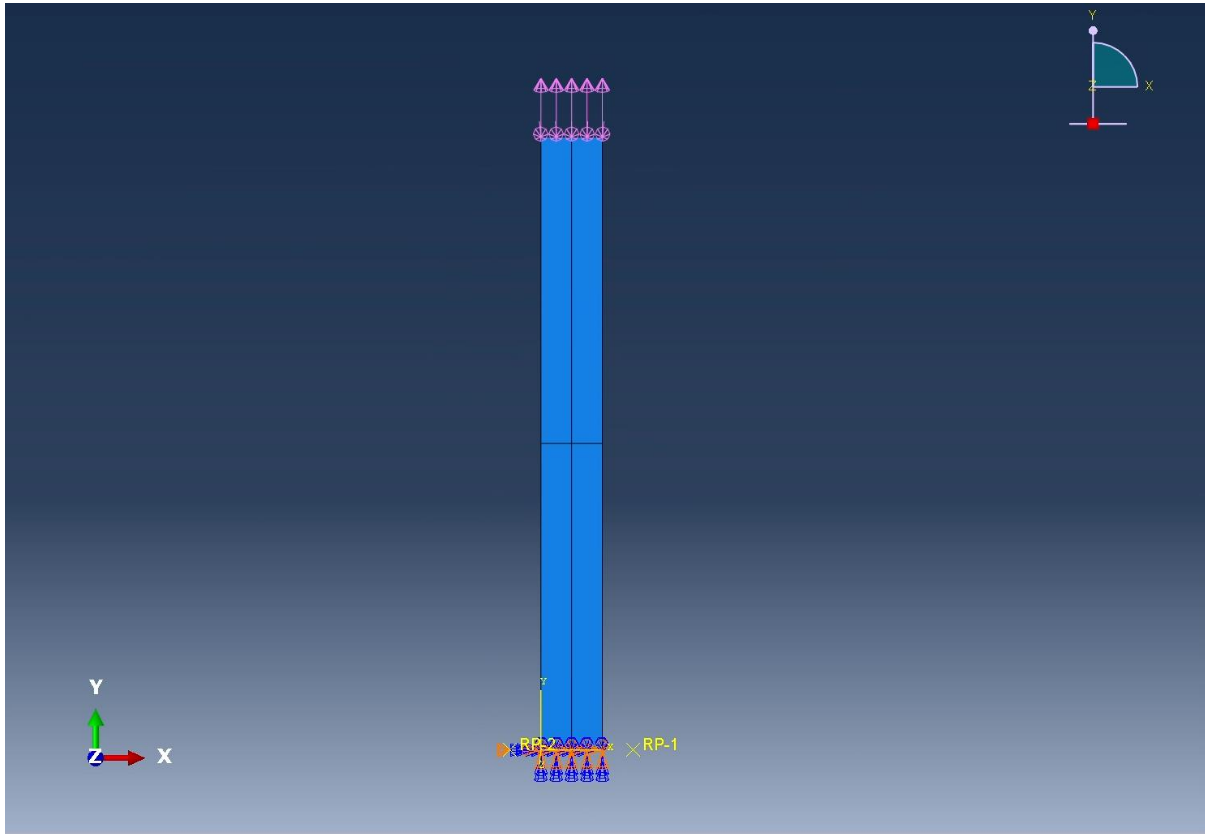




Module 6 Abaqus

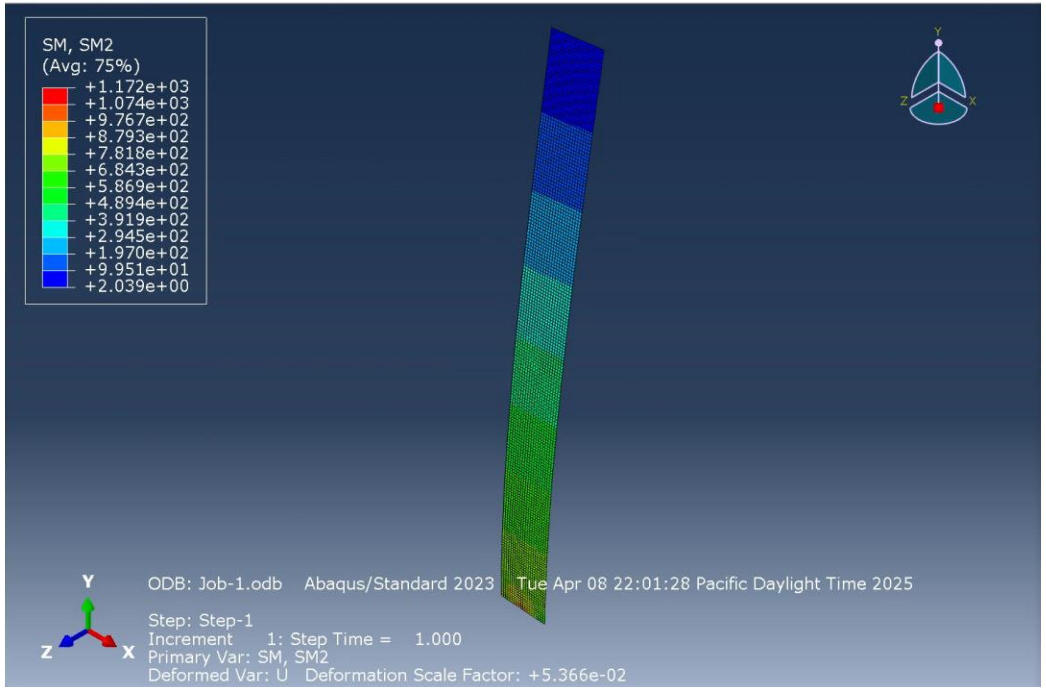
- Bottom is constrained
    - -45 and 40 applied load at the top of figure
        - Where purple arrows are
- Applied mesh





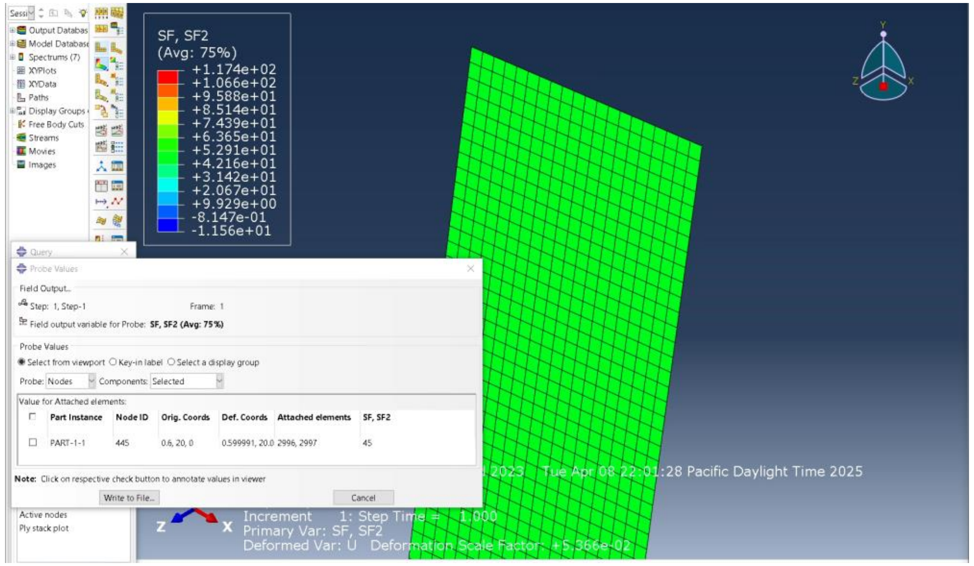
Module 6 Abaqus

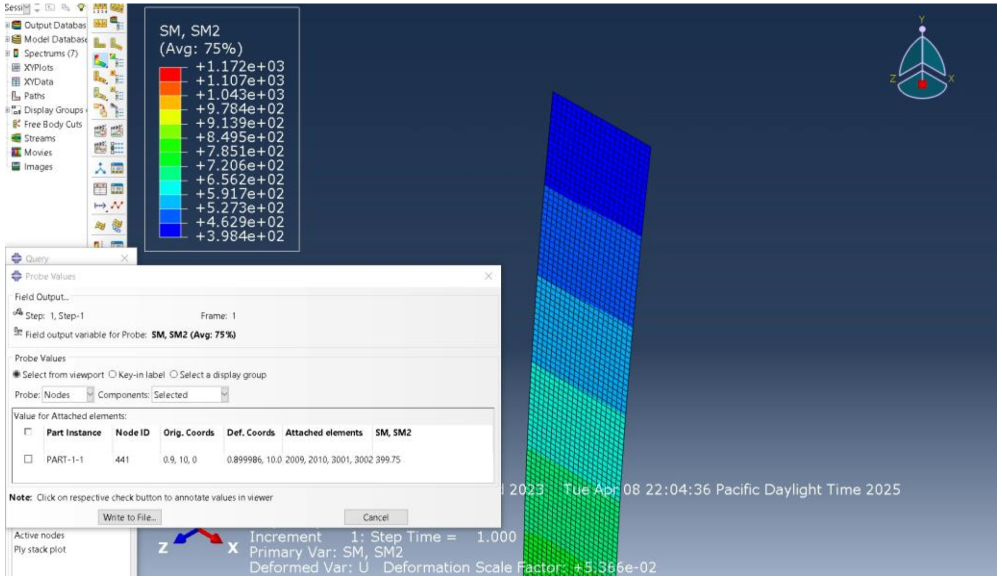
- SM results



#2 Module 6 Abaqus

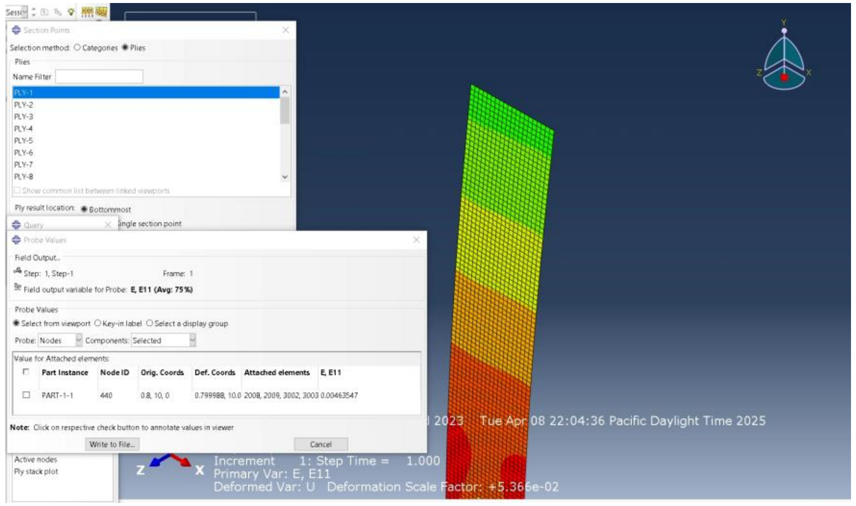
- Comparing Nodal values to excel spreadsheet like in the video
- The results are almost exact/comparable
- Excel sheet does a good job

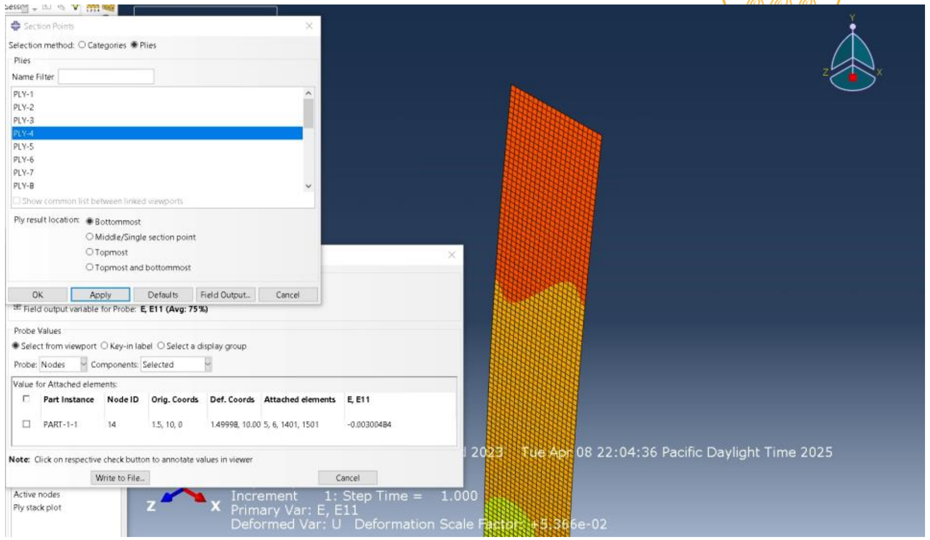


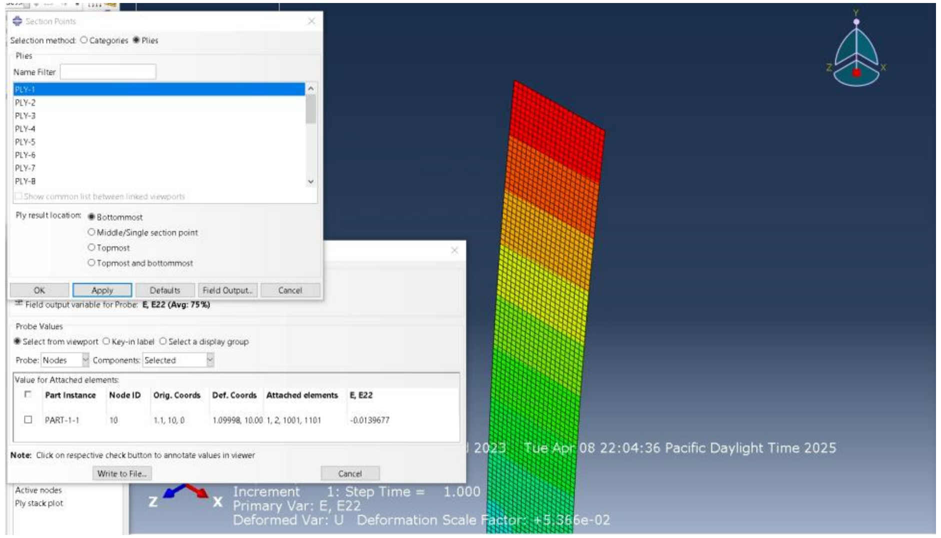


Module 6 Abaqus

- Comparing more nodal values to excel sheet



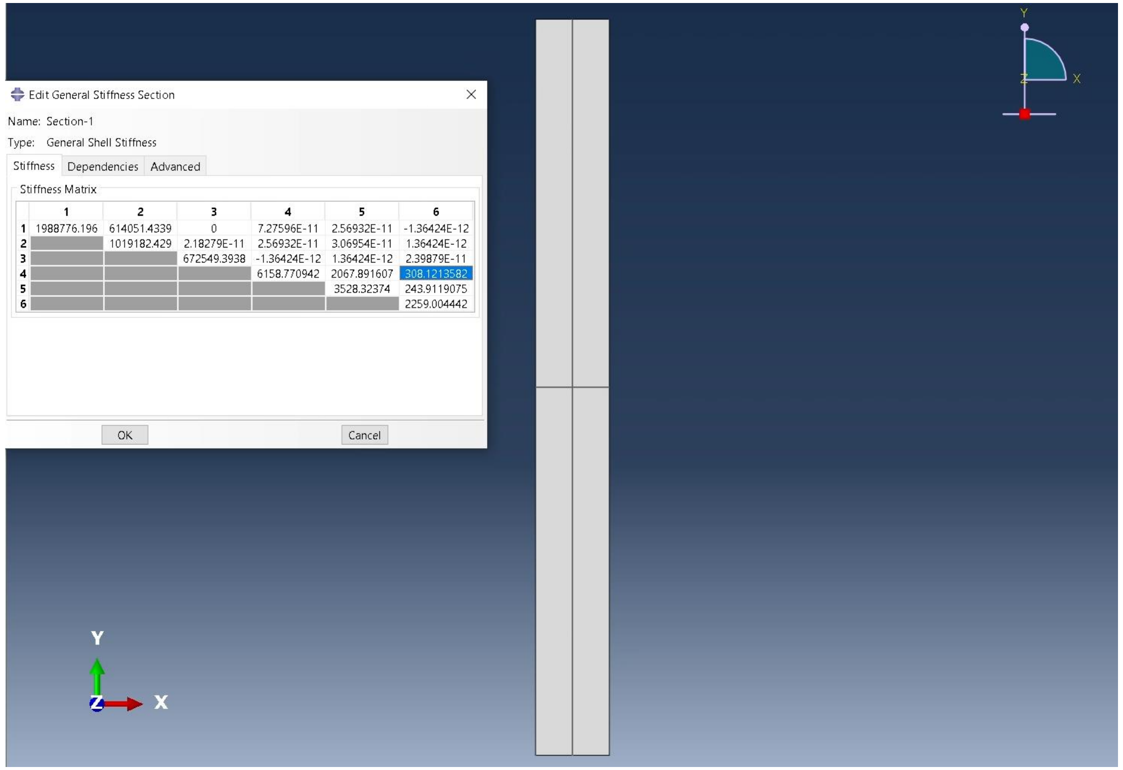




#2 Module 6 Abaqus

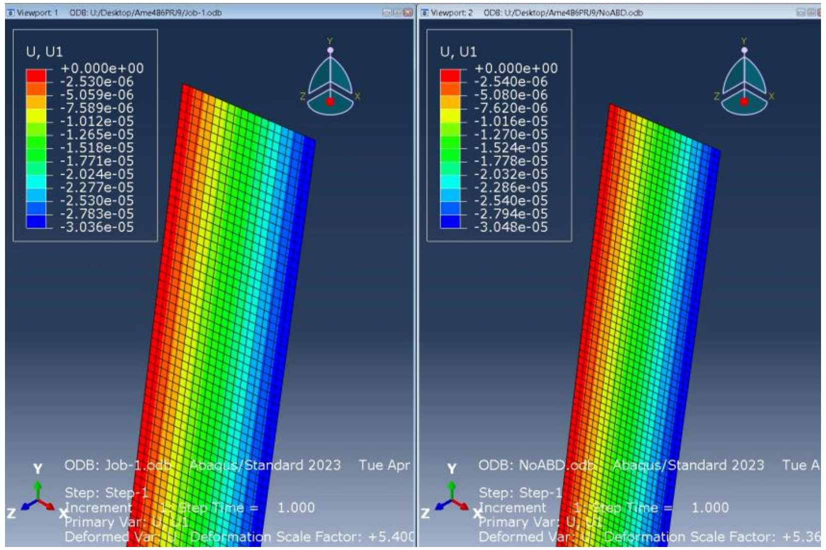
- Added in the ABD matrix for second model
  - Calculated in excel and inputted values to see how values compare to Abaqus

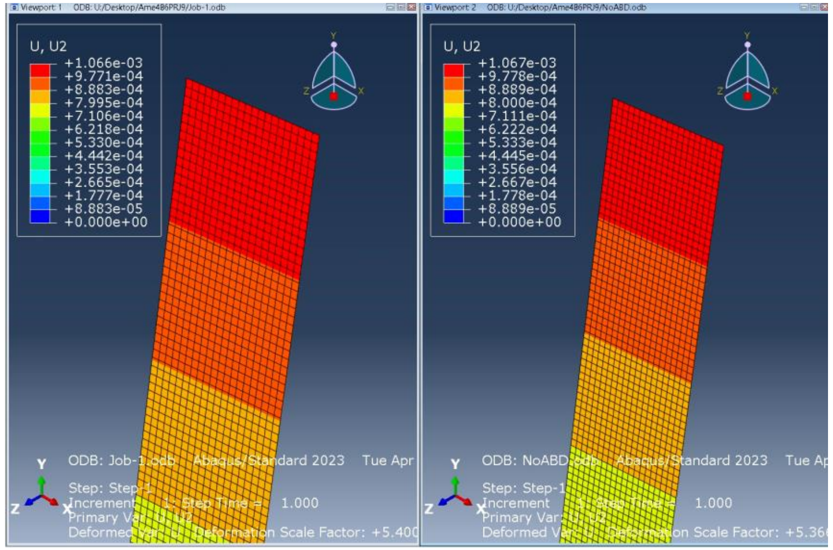
	1983776.196	614051.4339	0	7.27596E-11	2.56932E-11	-1.3642E-12
	614051.4339	1019182.429	2.18279E-11	2.56932E-11	3.06954E-11	1.36424E-12
ABD Matrix:	0	2.18279E-11	672549.3938	-1.36424E-12	1.36424E-12	2.39879E-11
	7.27596E-11	2.56932E-11	-1.36424E-12	6158.770942	2067.891607	308.1213582
	2.56932E-11	3.06954E-11	1.36424E-12	2067.891607	3528.32374	243.9119075
	-1.3642E-12	1.36424E-12	2.39879E-11	308.1213582	243.9119075	2259.004442

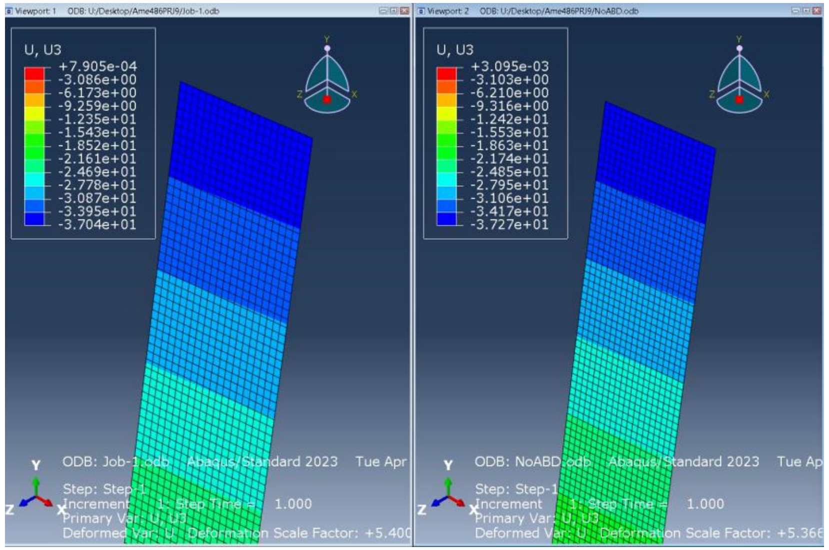


Module 6 Abaqus

- On the left of the viewport, is the hand calculated ABD matrix
- On the right of the viewport is the Abaqus calculated values based on engineering constants
- We can see the results are almost exactly the same

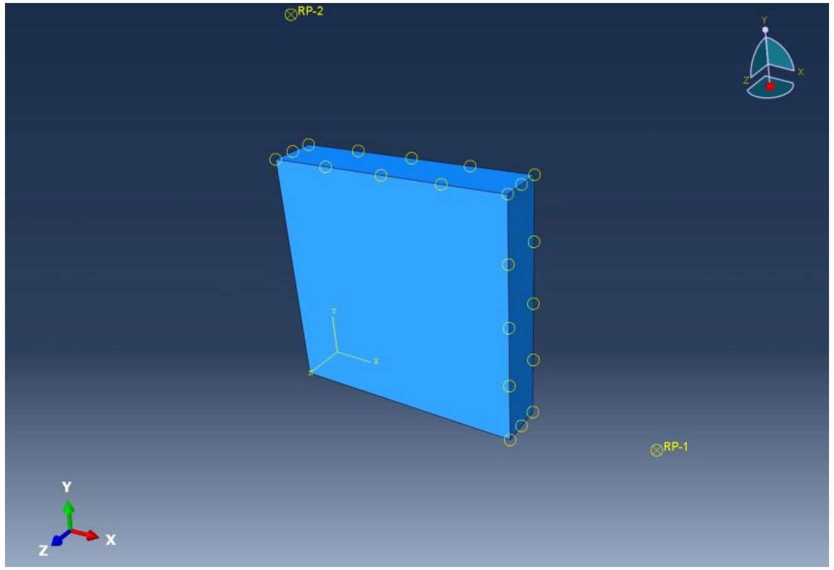


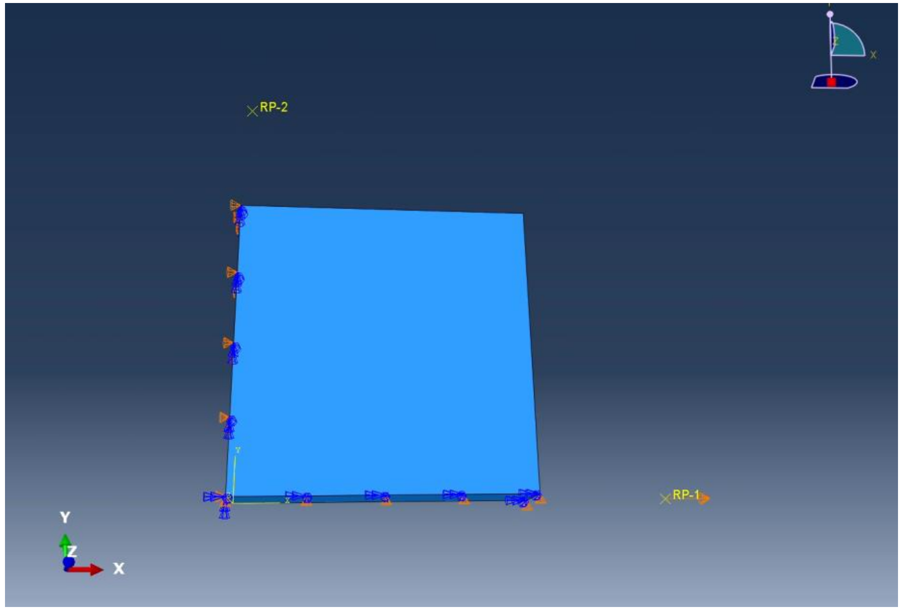




Module 3 Abaqus

- Model 1
- Using the effective properties from Chou's theory and using one element through the thickness
- This is the model setup with constraints shown below

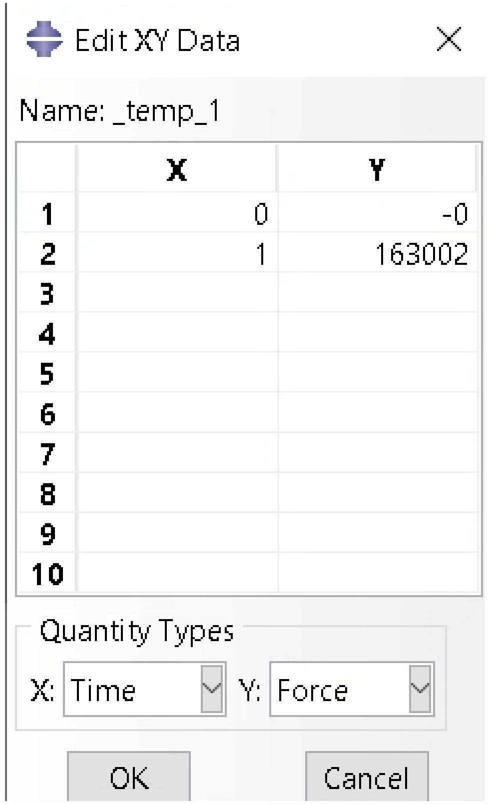




#2

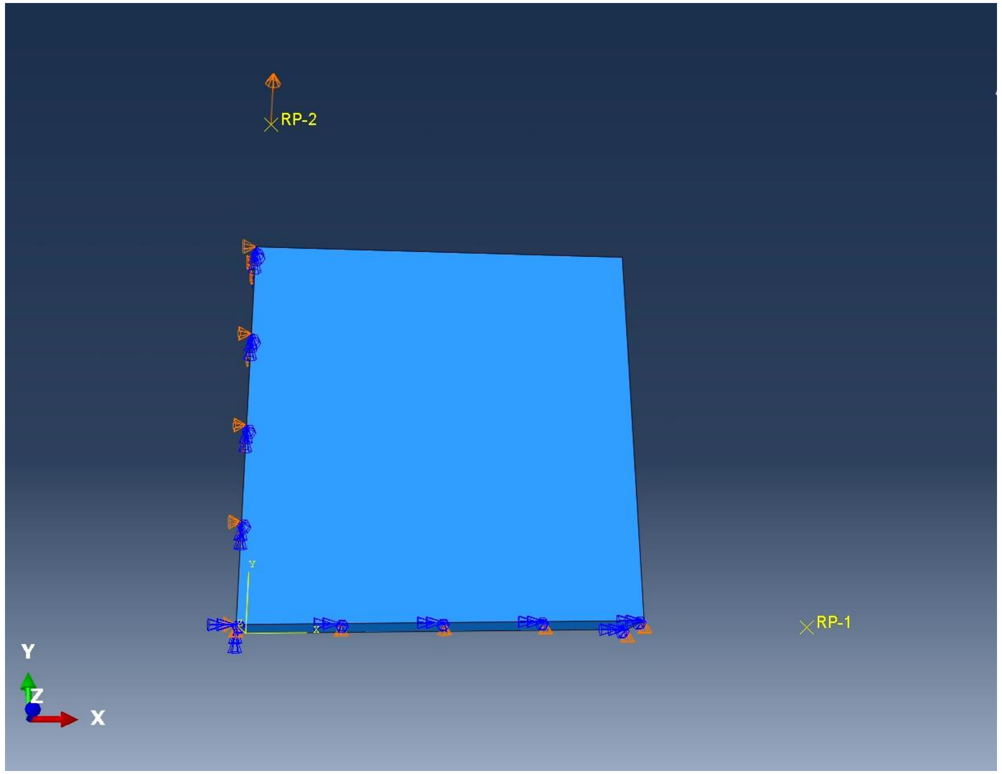
Module 3 Abaqus

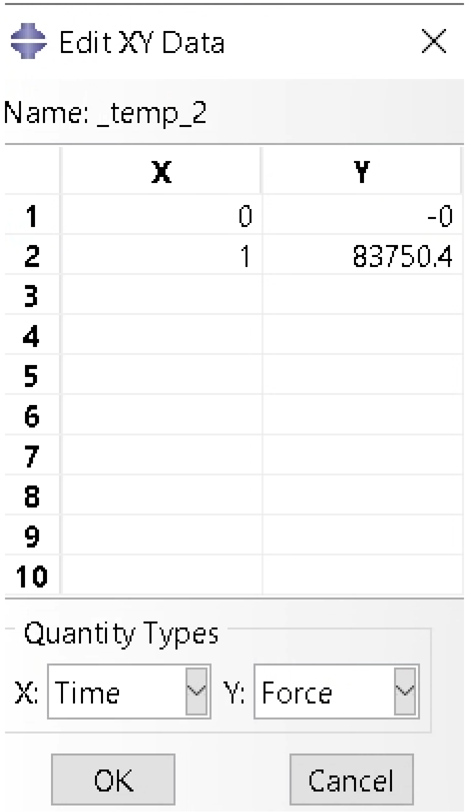
- Model 1 – reference point 1 load
- Matches the online video



#2 Module 3 Abaqus

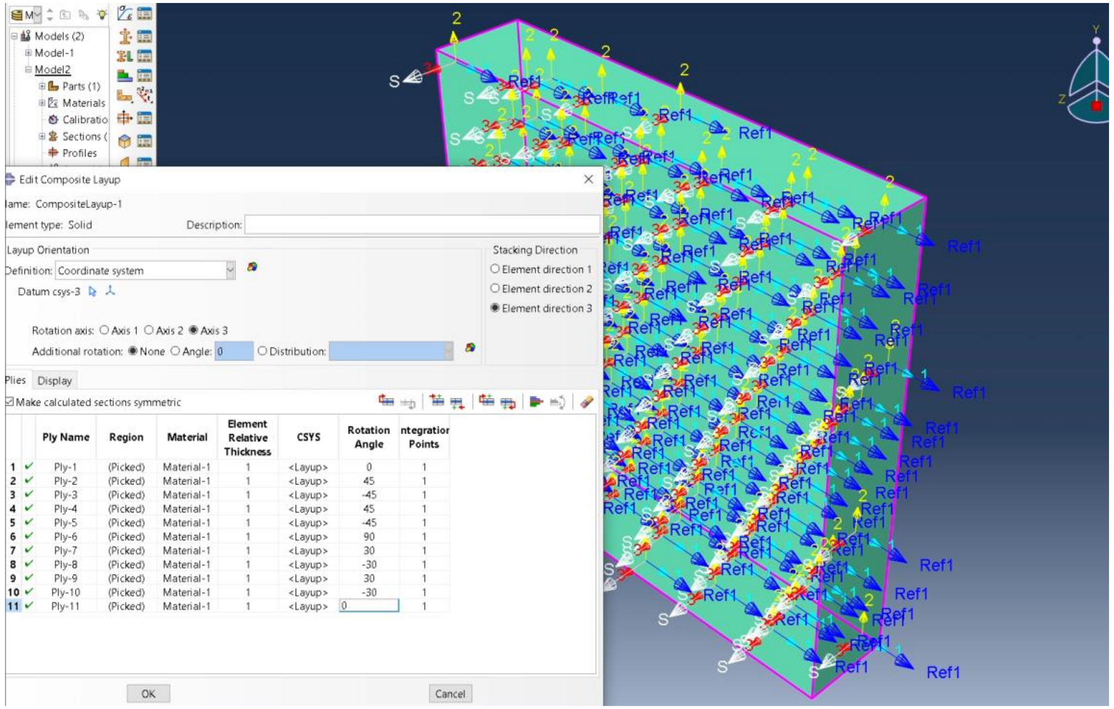
- Model 1- reference 2 load
- Matches online video

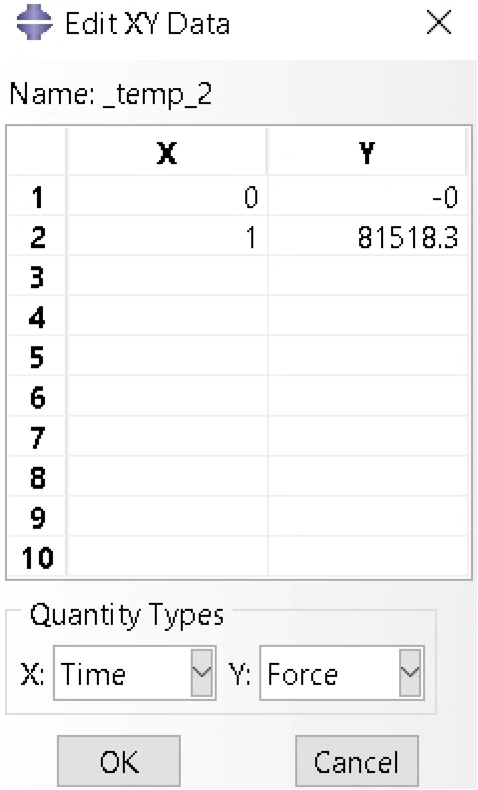




Module 3 Abaqus

- Model 2 – Abaqus calculated effective properties
- Solid section where the stack direction = 3
- Results for reference point 2 shown to the right (Y-direction)
- Matches data from model 1

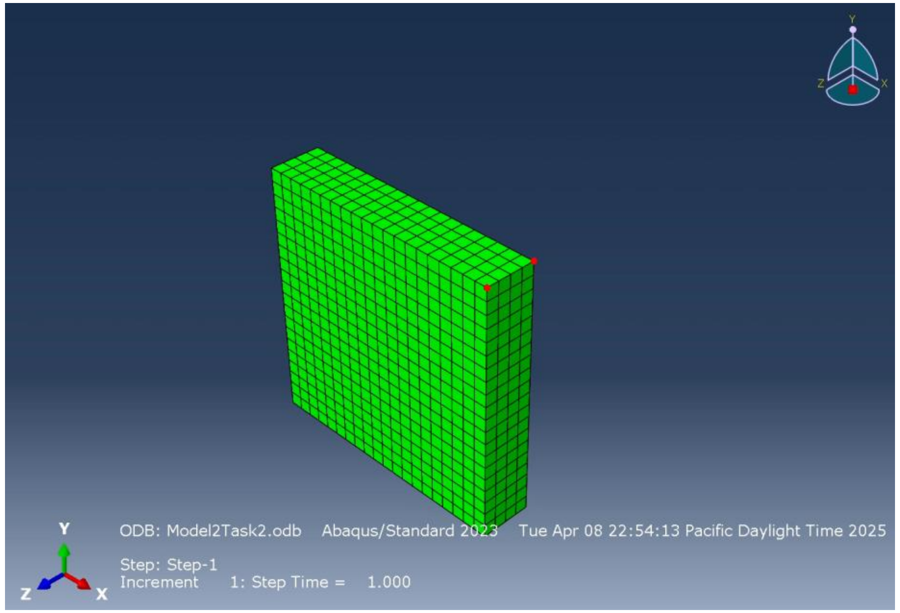


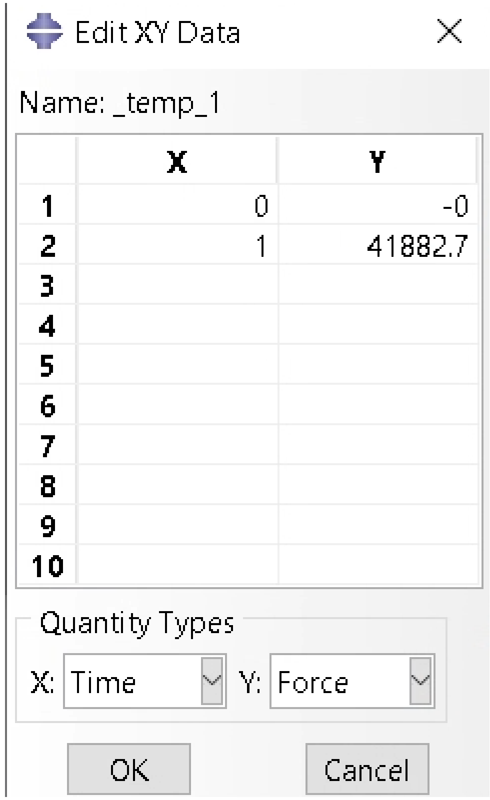


#2

Module 3 Abaqus

- Model 2 – reference 2
- 41882.7 matches closely with online data

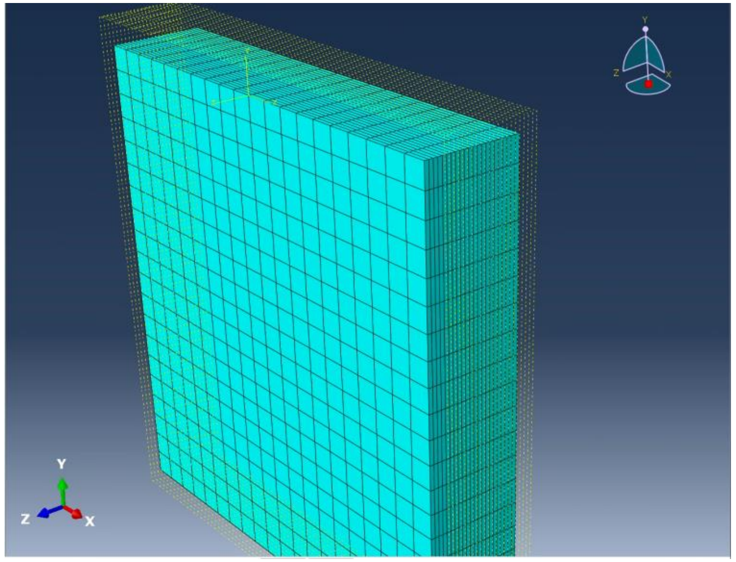


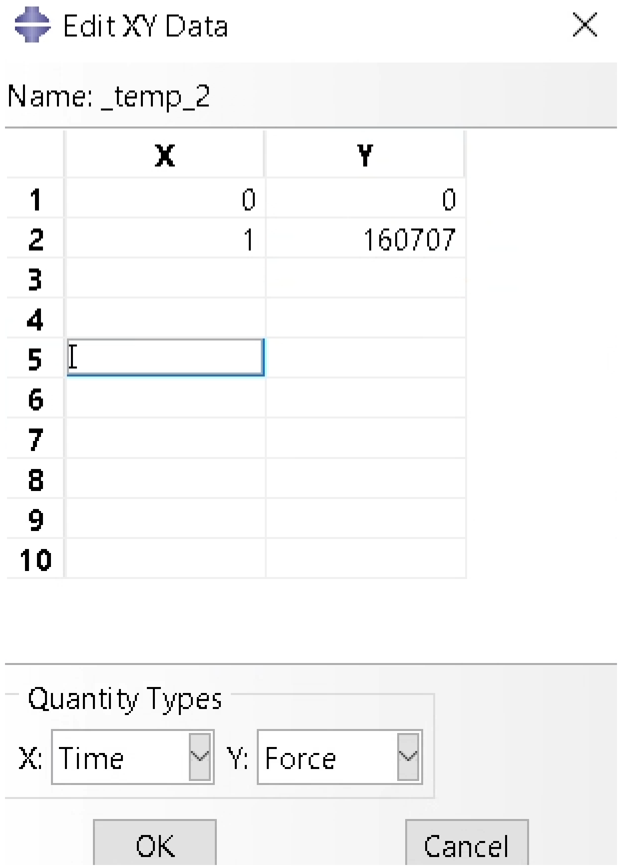


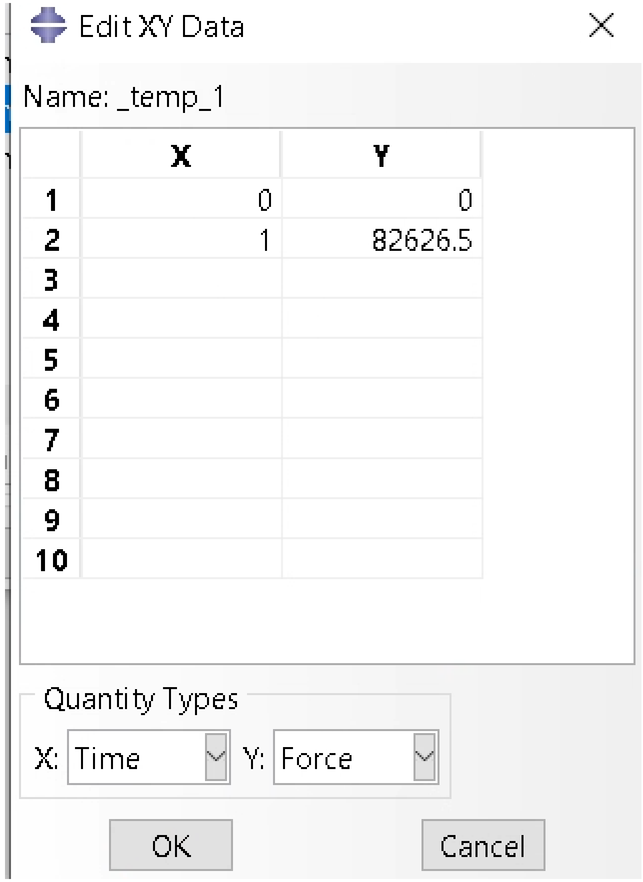
#2

Module 3 Abaqus

- Model 3 – Results shown
- Every ply was modeled in the part
  - All 22 ply's
- Results match video guidelines

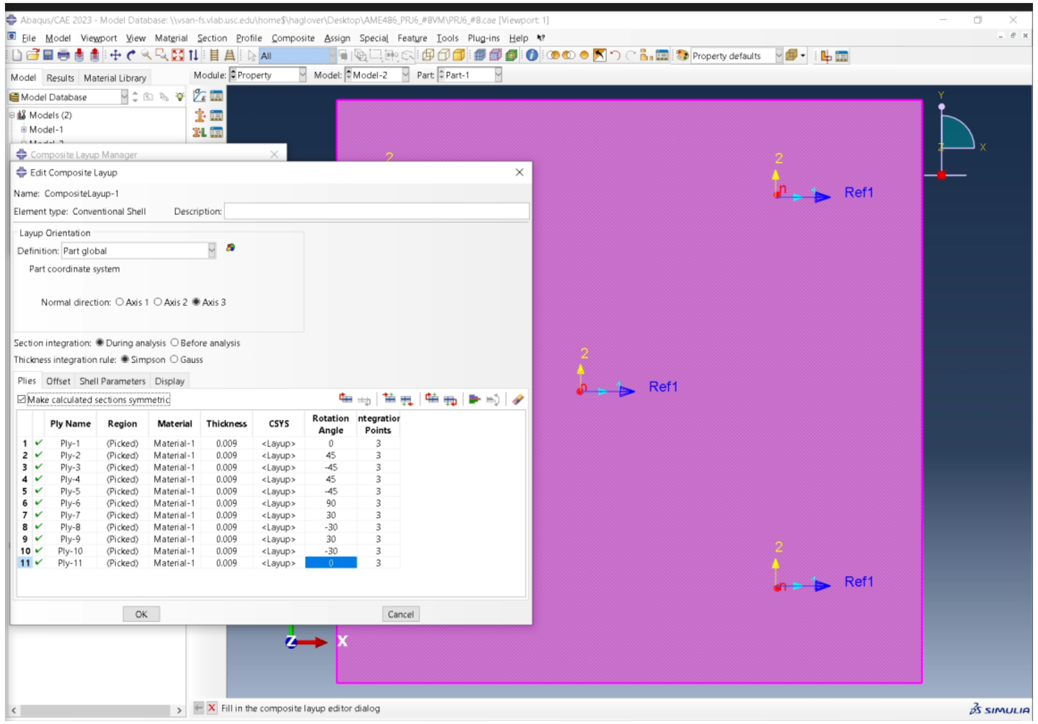


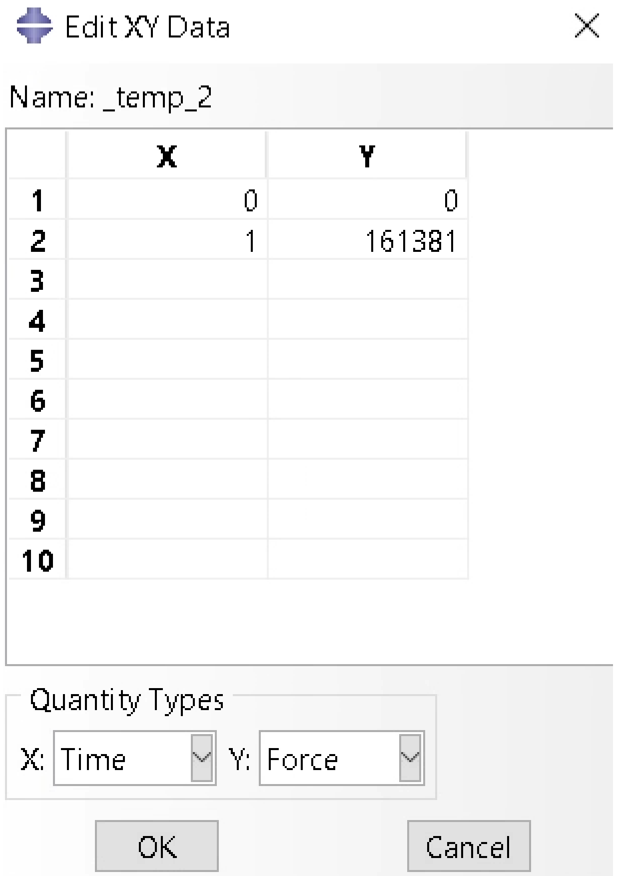




Module 3 Abaqus

- Model 4 – shell element
- Results shown to the right
- Matches online video





Edit XY Data

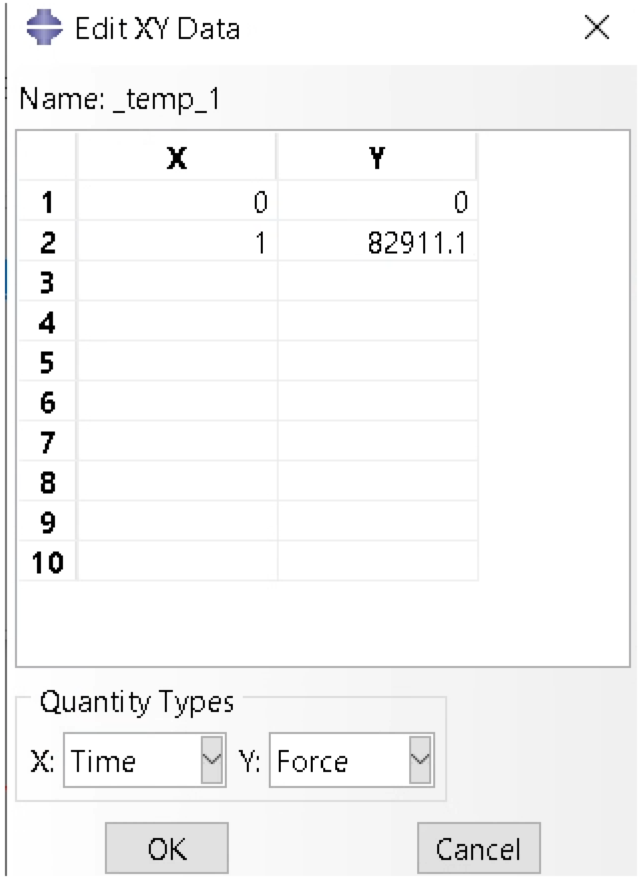
Name: _temp_2

	X	Y
1	0	0
2	1	161381
3		
4		
5		
6		
7		
8		
9		
10		

Quantity Types

X: Time Y: Force

OK Cancel



Edit XY Data

Name: _temp_1

	X	Y
1	0	0
2	1	82911.1
3		
4		
5		
6		
7		
8		
9		
10		

Quantity Types

X: Time Y: Force

OK Cancel

#2

Module 3 Abaqus

- Conclusion For Module 3, 5, and 6
- All approaches work when characterizing a part
    - That being said, Model 1 - where effective properties are input and a single element is used through the entire thickness - is less accurate compared to a more detailed model
- Modeling each ply individually using datum planes and explicitly cutting out each layer provides greater accuracy of composite behavior
- The ply-level approach can capture the true stress distribution
- Using shell elements can also characterize the mid plane stress fairly accurately and can save time