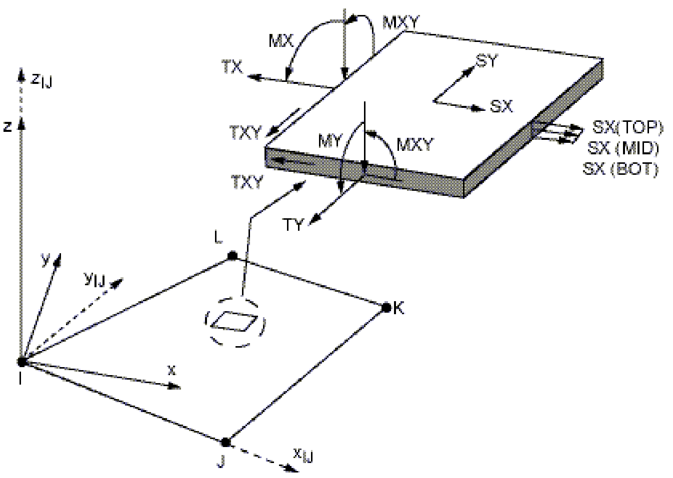
SHELL ELEMENTS
BENDED PLATE AND THIN-WALLED BEAM

1. INTRODUCTION

Shell elements geometry is defined by the nodes in the middle surface. Thickness I applied as a parameter. Stress system includes membrane and bending stresses. Each layer parallel to the middle surface acts in plane stress. Distribution of normal and shear stress along thickness is linear (see Figure below). Shell elements can be used to model thin walled structures (vessels and plates) as well as thin-walled beams. There are six degrees of freedom (DOF) at each node: three linear displacements and three angles of rotation.



SHELL Element **Stress Output**

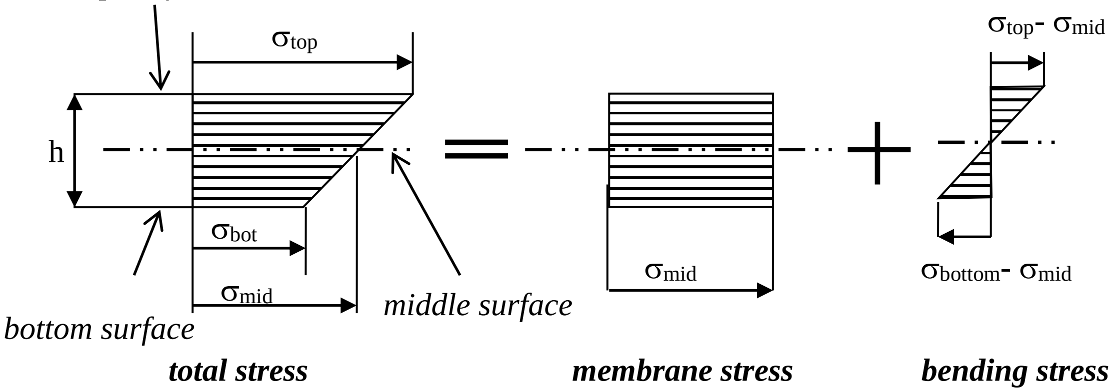


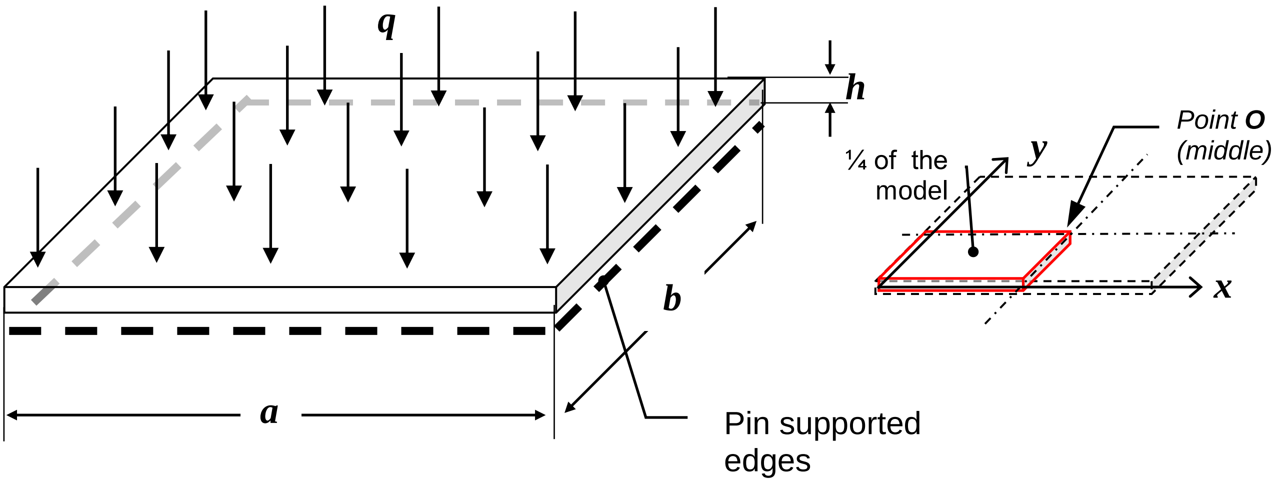
Fig. The membrane and bending stress components in the shell

2. PROBLEM DESCRIPTION

2.1. Bending of the rectangular plate

The goal of the analysis is to find deflection and stress components in rectangular plate supported along edges on pin supports and loaded with constant surface load ***q***.

<u>Data:</u> q=0.1MPa, a=200 mm, b= 300mm, h=4mm, $E=2\cdot10^5$ MPa, ν=0.3

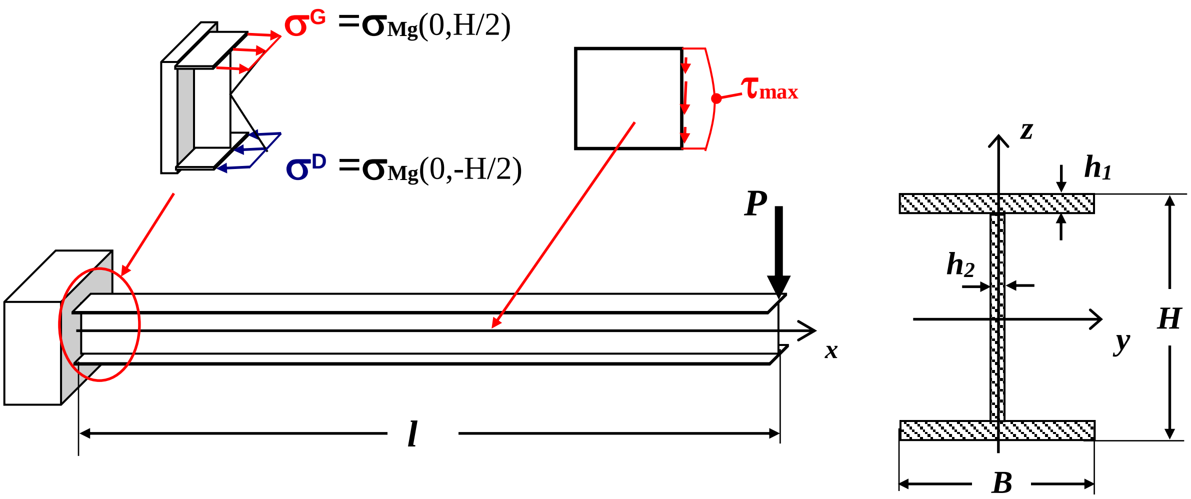


<u>Stress components and deflection at point O</u>:

$$\sigma_x = 0.0812\cdot\frac{6qa^2}{h^2},\quad \sigma_y = 0.0498\cdot\frac{6qa^2}{h^2},\quad f = 0.00782\cdot\frac{12qa^4(1-\nu^2)}{Eh^3}$$

2.2. Bending of the thin-walled beam

The goal of the exercise is to find deflection and stresses in the thin-walled cantilever beam loaded with concentrated load.
Data: P=10 kN, l=5 m, B= 100mm, H= 240mm, h_1= 13mm, h_2= 9mm, $E=2\cdot10^5$ MPa, ν=0.3



$$\sigma(x,z) = \frac{-Mg(x)\cdot z}{Jy},$$ gdzie: $Mg(x) = P\cdot(x-l)$, $Jy = \frac{B\cdot H^3}{12} - \frac{(B-h_2)\cdot(H-2\cdot h_1)^3}{12}$

$$\tau_{\max} \cong \frac{P}{(H-2h_1)\cdot h_2}$$

$$f_{\max} = \frac{P\cdot l^3}{3EJ_y}$$

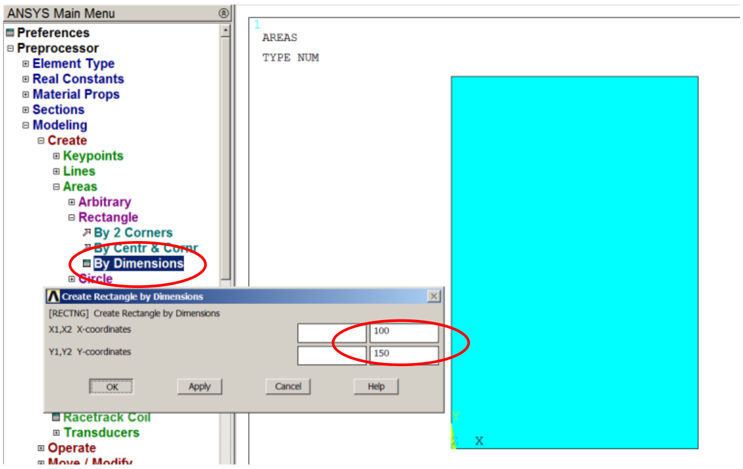
3. TYPICAL COURSE OF NUMERICAL ANALYSIS

Taking double symmetry of the problem we can built ¼ of the analyses plate. Convenient units are: *mm, N, MPa*.

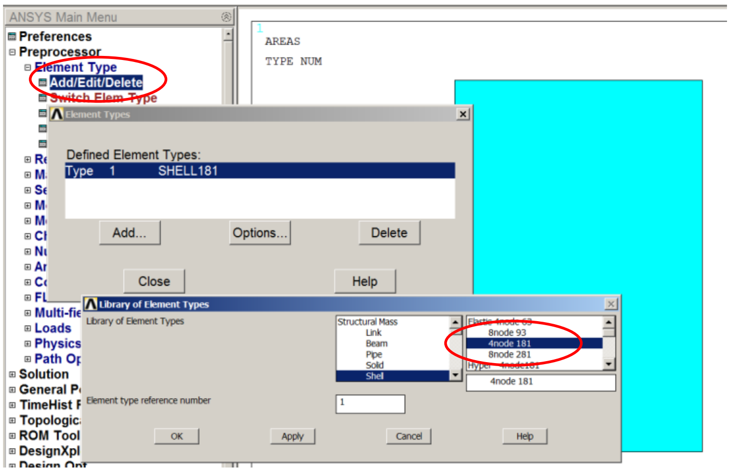
3.1. Bending of the plate

3.1.1 Preprocessor

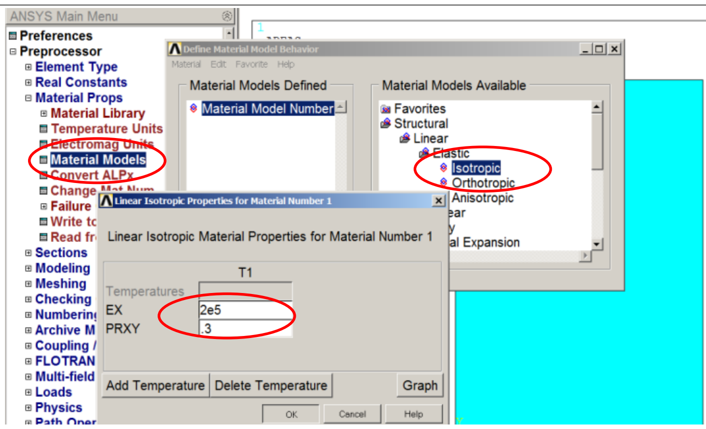
1. Create rectangle: **Preprocessor**>Create>Rectangle> By Dimensions



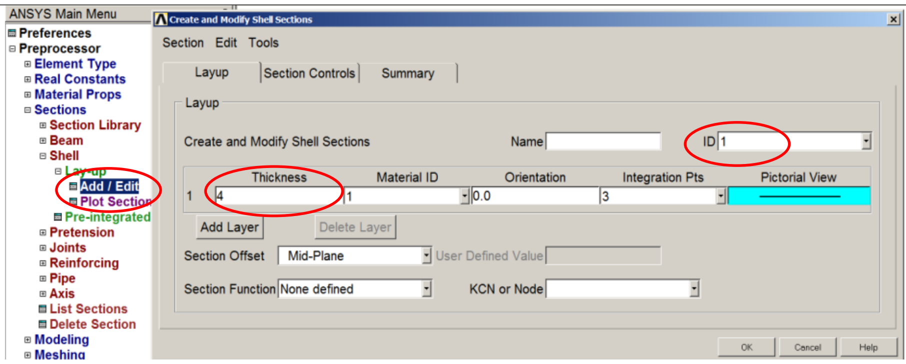
2. Select element type: **Preprocessor**>Element Type>Add> SHELL181



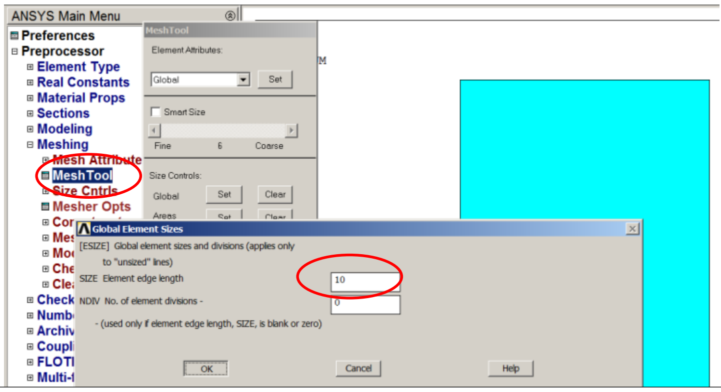
3. Define material properties: **Preprocessor**>Material Props>Material Models: *Structural/Linear/Elastic/Isotropic: EX=2e5MPa, PRXY=0.3*



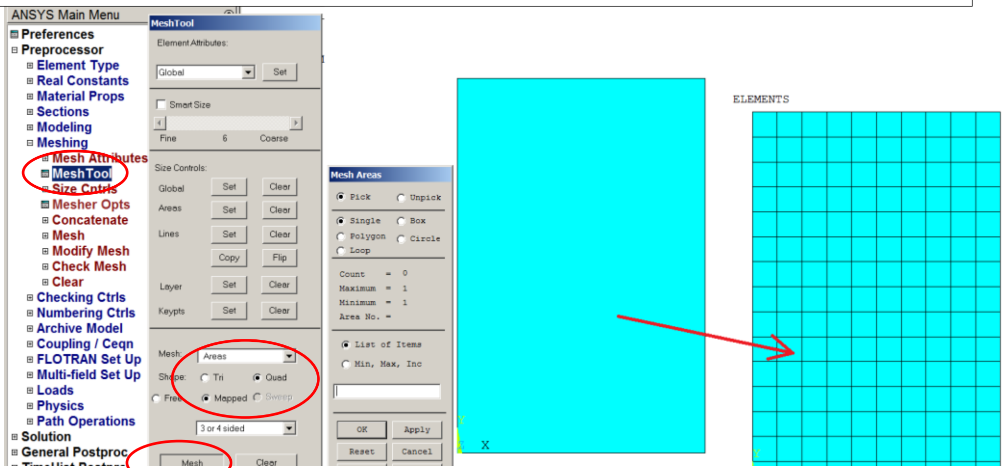
4. Define element thickness: **Preprocessor**>Section>Shell> Lay-up>Add/Edit



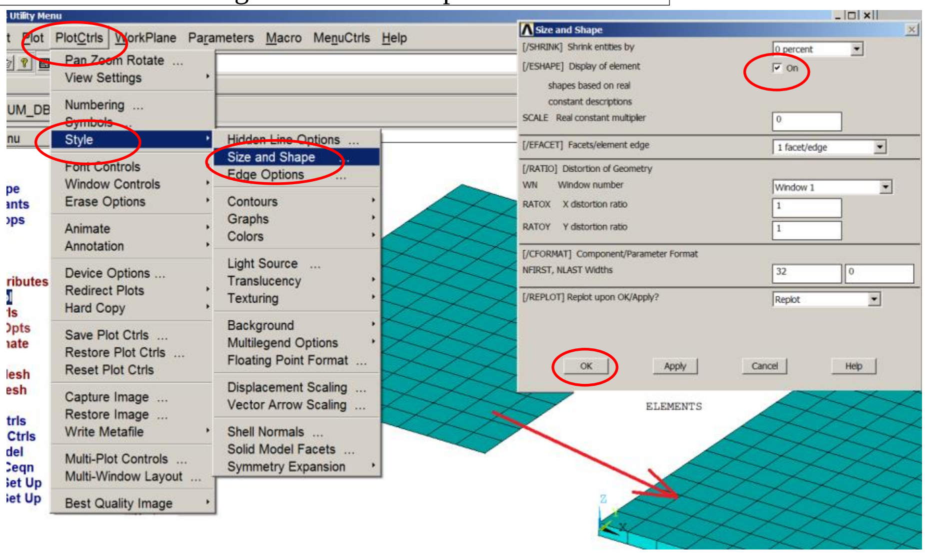
5. Define size control: **Preprocessor**>Meshing>Mesh Tool>SizeCtrl>Global



6. Generate mesh: **Preprocessor**>Meshing>Mesh Tool>Mesh>Areas *(Quad)*



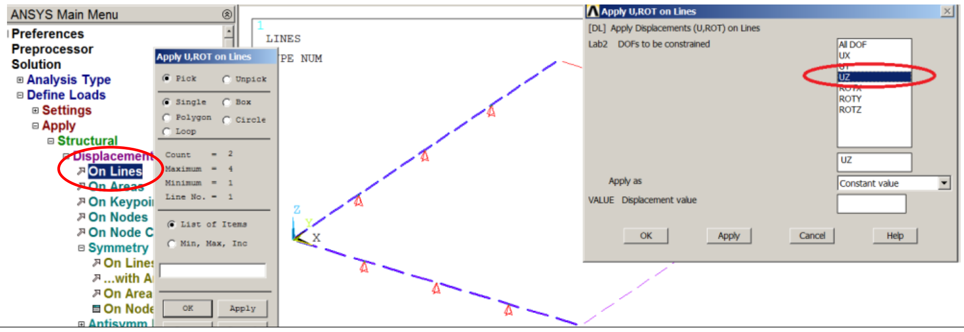
8. Plot elements using thickness description



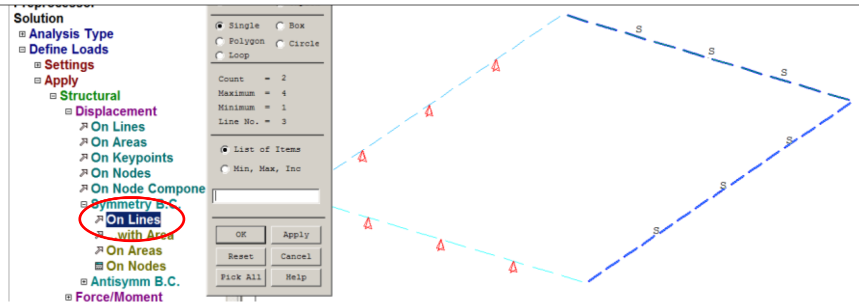
3.1.2. Solution

<u>Define boundary conditions</u>:

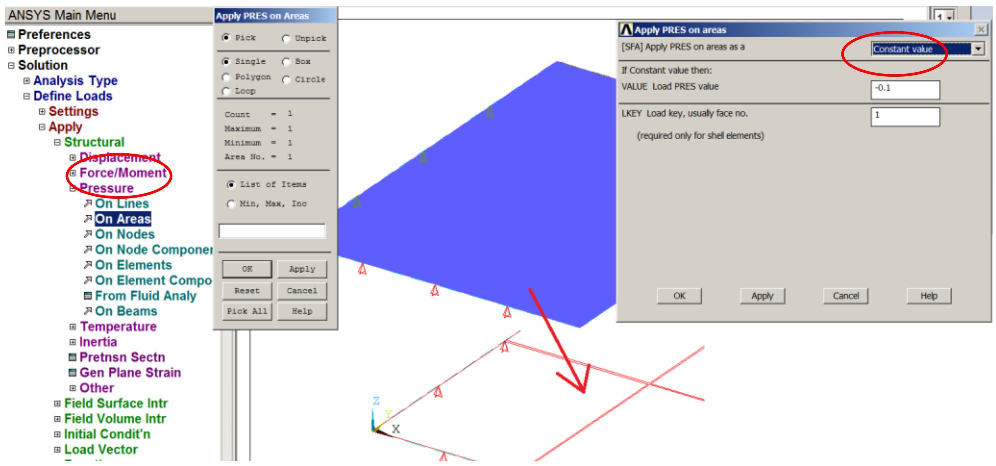
9. <u>Define pin support on along edges</u>: **Solution**>Define Loads>Apply>Structural>Dispalcements>On Lines



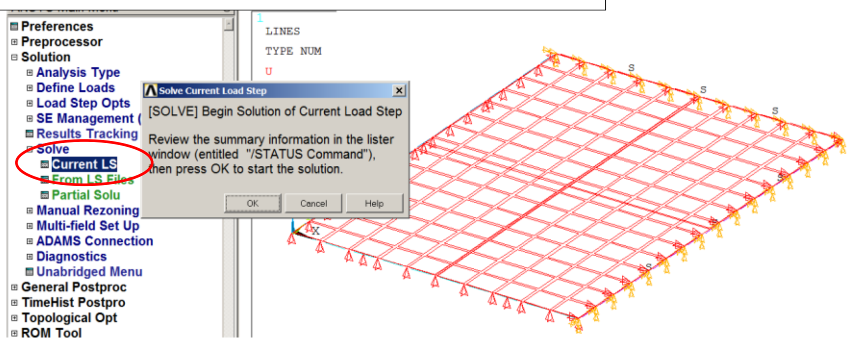
10. <u>Define symmetry B.C. on lines</u>: **Solution**>Define Loads>Apply>Structural >Dispalcements>Symmetry B.C.>On Lines



11. <u>Apply surface load</u>: **Solution**>Define Loads>Apply>Structural>Pressure>On Areas



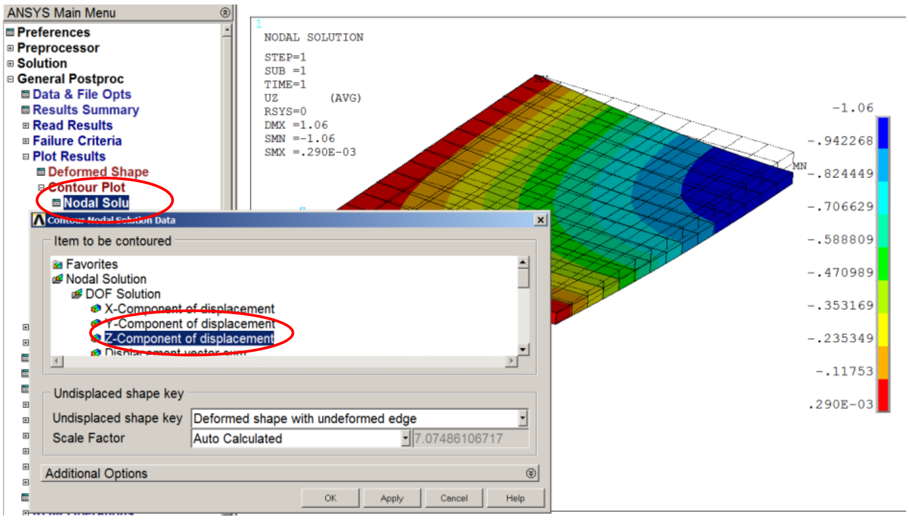
12. Solve the problem: **Solution**>Solve> Current LS



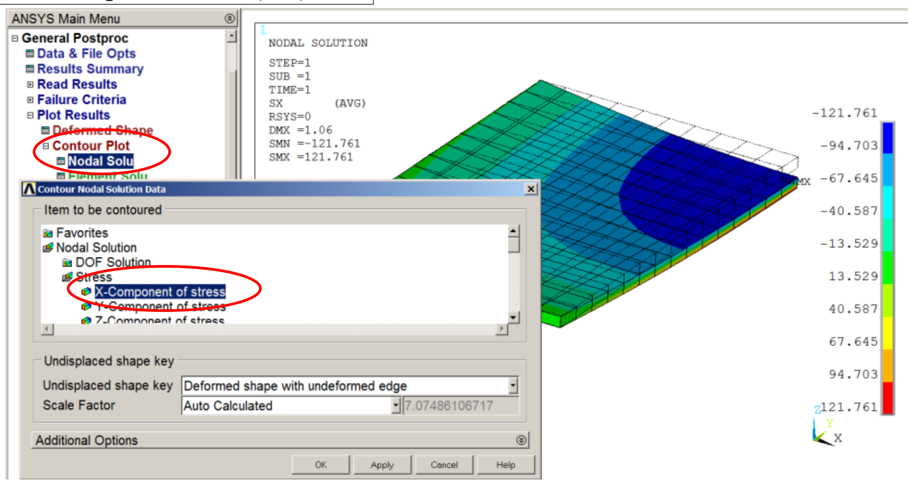
3.1.3. General postprocessor

Show the results as contour maps:
Show displacements normal to the plate (UZ), bending stress: stress components (SX, SY)

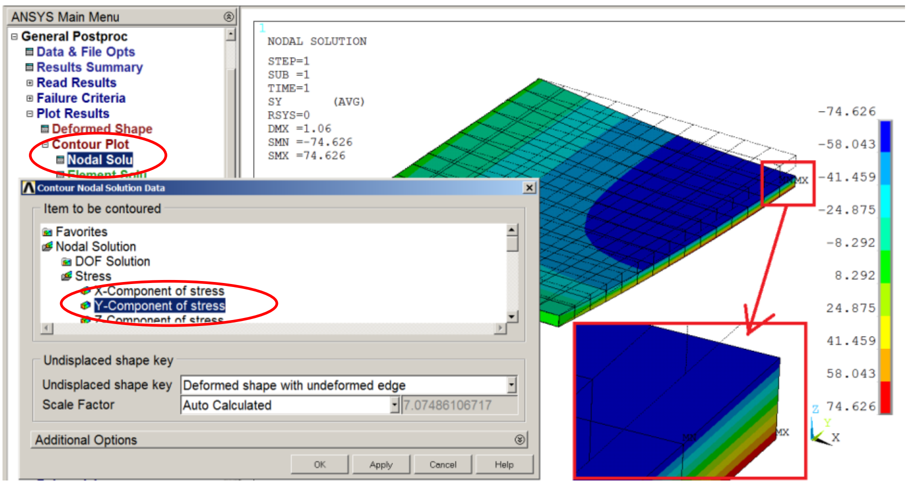
13. Plot displacements UZ



14. Plot stress component in X (SX)



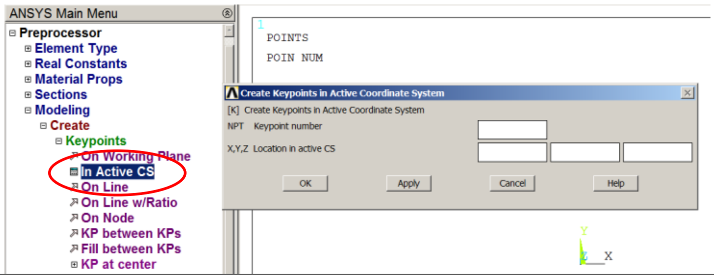
15. Plot stress component in Y (SY)



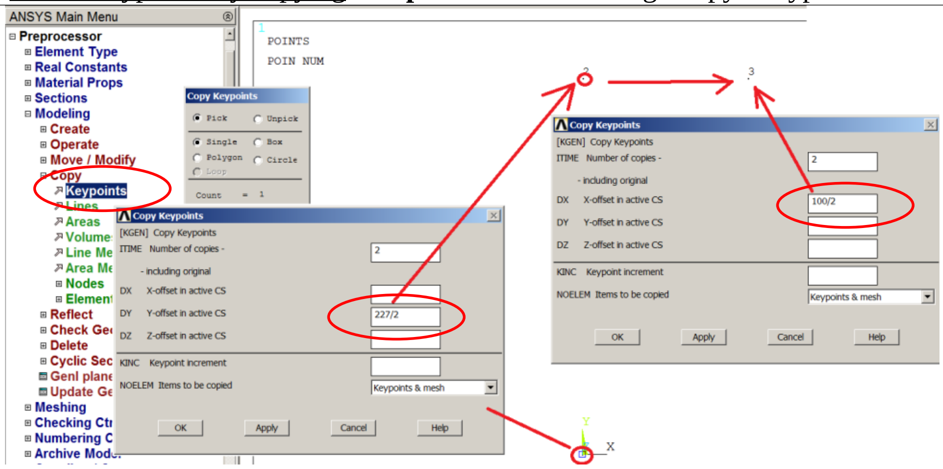
3.2. Thin-walled beam

3.2.1 Preprocessor

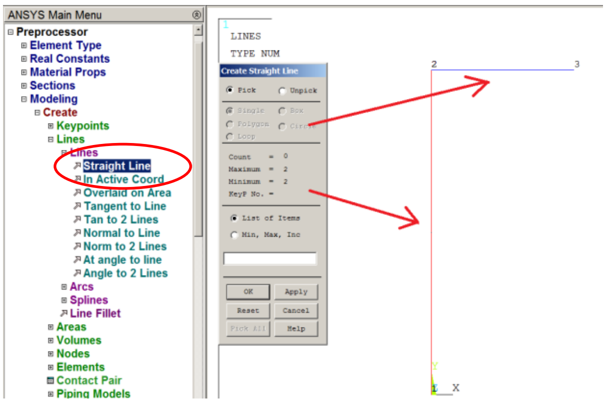
1. Create keypoint in central point (0,0,0): **Preprocessor**>Create>Keypoint>In Active CS



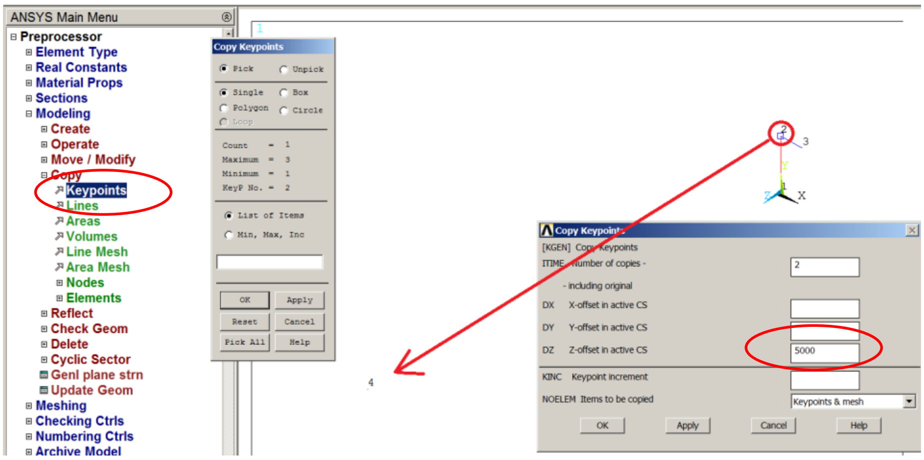
2. Create keypoints by copying: **Preprocessor**>Modeling>Copy>Keypiont



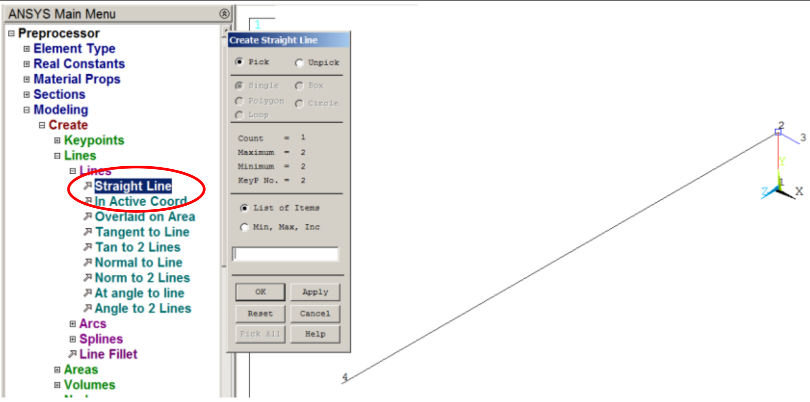
3. Create lines by keypoints: **Preprocessor**>Modeling>Create>Lines> Stright Line



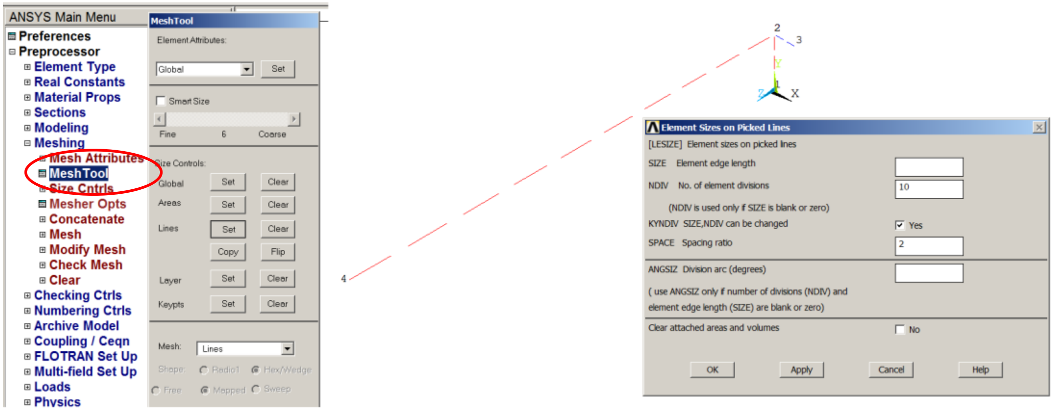
4. Create keypoint by copying: **Preprocessor**>Modeling>Copy>Keypiont



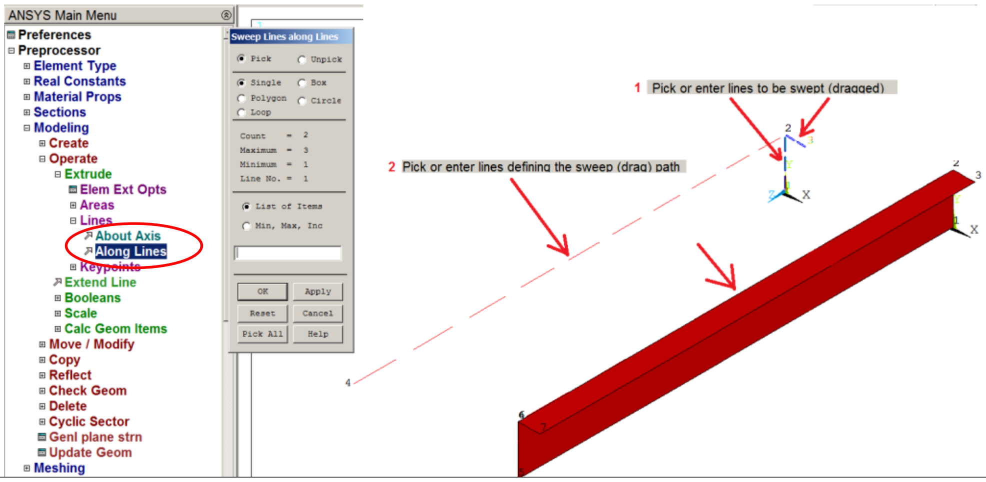
5. Create lines by keypoints: **Preprocessor**>Modeling>Create>Lines> Stright Line



6. Define size control on lines: **Preprocessor**>Meshing>Mesh Tool>SizeCtrl>Lines

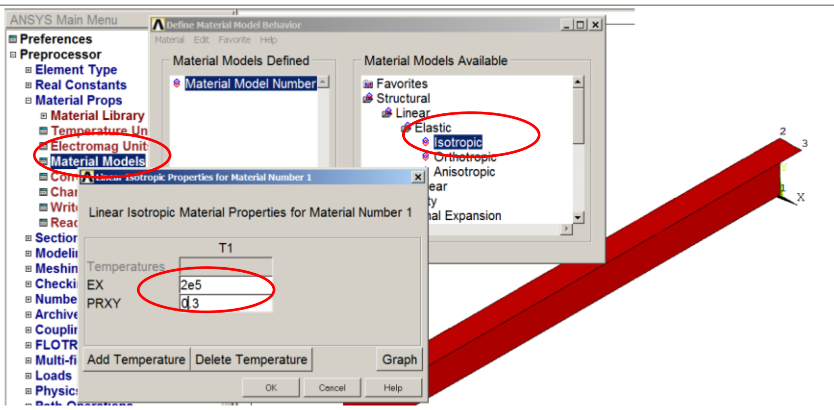


7. Extrude lines along line: **Preprocessor**>Modeling>Operate>Extrude>Lines>Along Lines

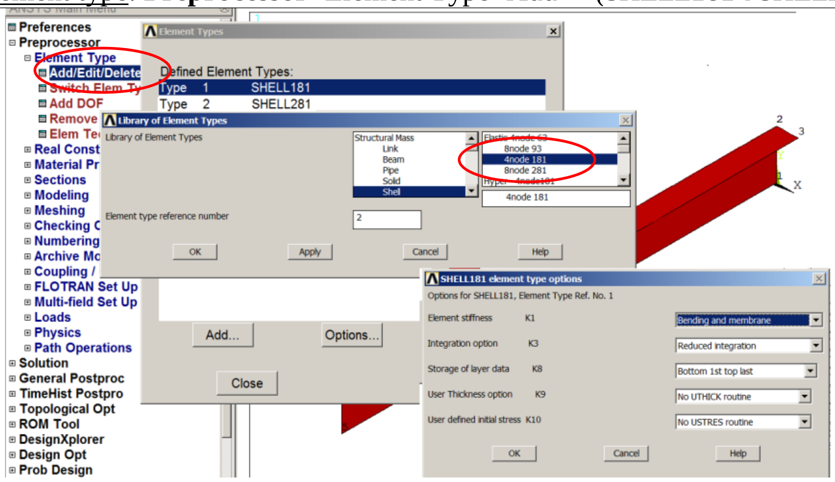


8. Define material properties: **Preprocessor**>Material Props>Material Models:

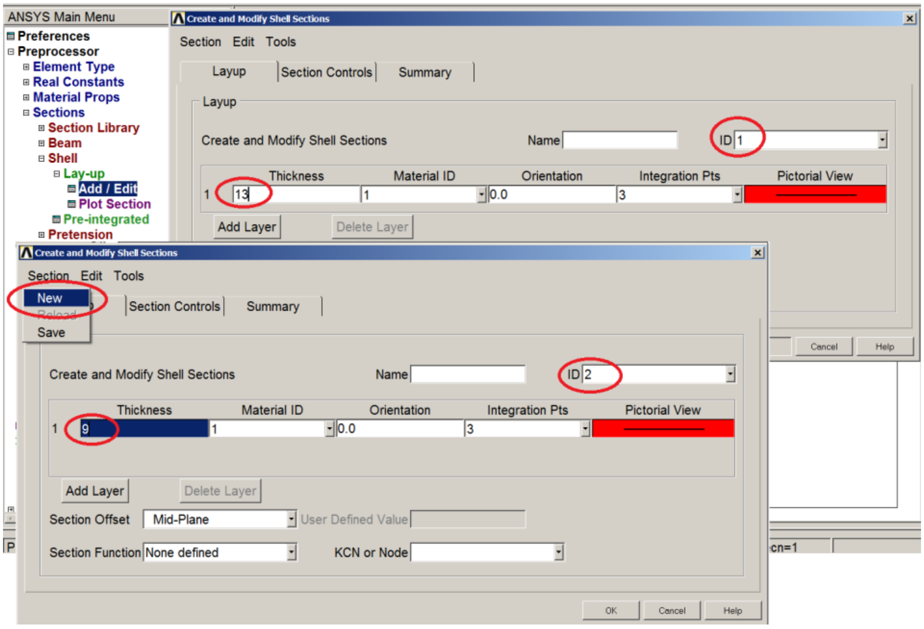
Structural/Linear/Elastic/Isotropic: EX=2e5MPa, PRXY=0.3



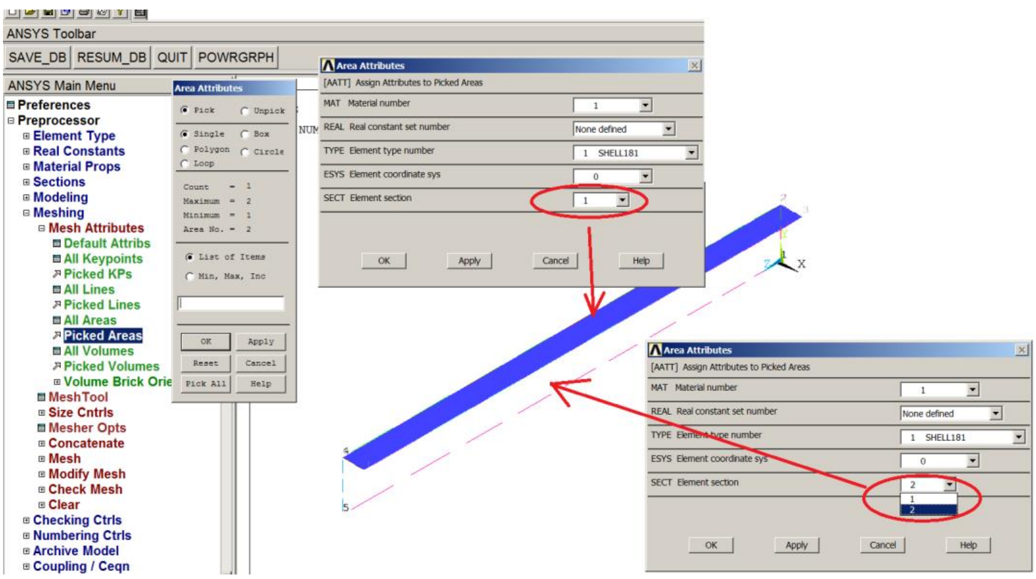
9. Select element type: **Preprocessor**>Element Type>Add> *(SHELL181 i SHELL281)*



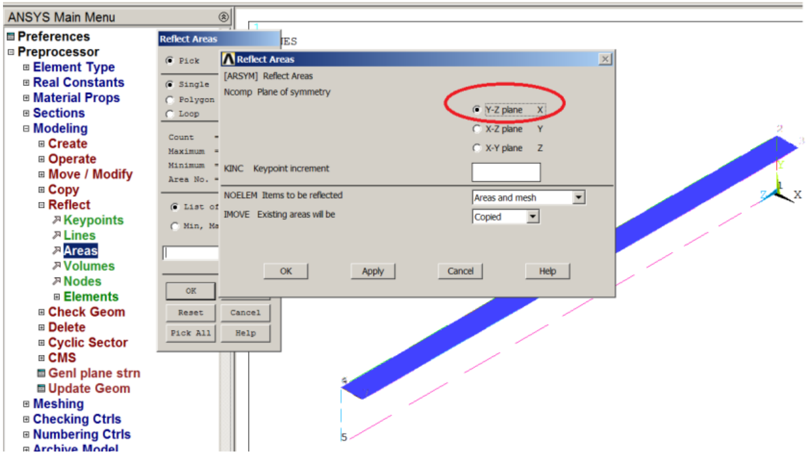
10. Define section parameters for shell elements: **Preprocessor**>Section>Shell> Lay-up>Add/Edit



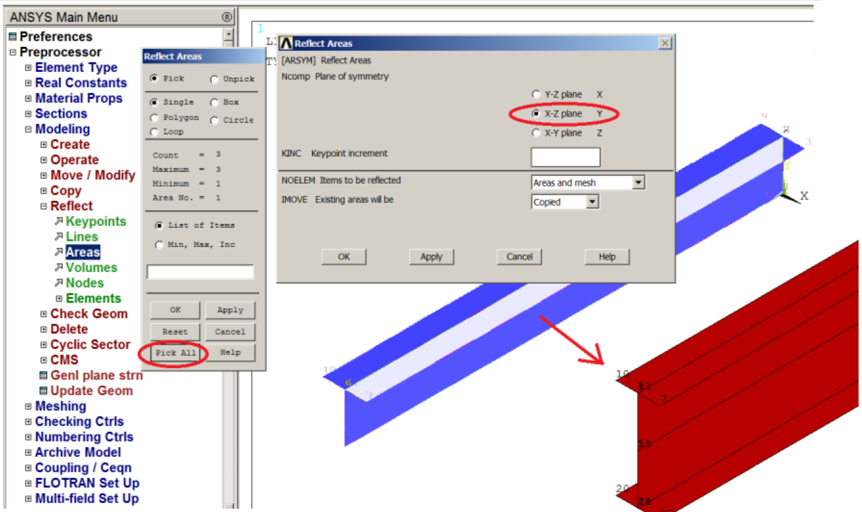
11. Define attributes on areas: **Preprocessor**>Meshing>Mesh Attributes> Picked Areas



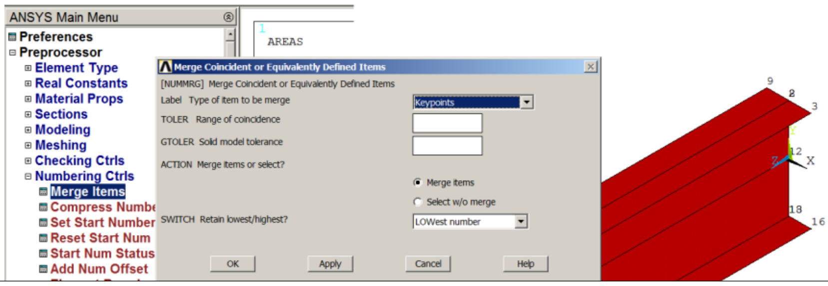
12. Reflect areas: **Preprocessor**>Modeling>Reflect>Areas



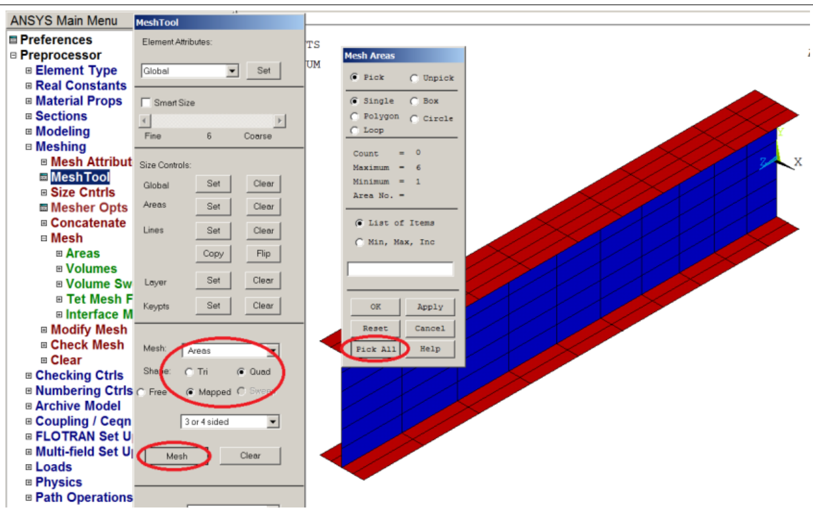
13. Reflect areas: **Preprocessor**>Modeling>Reflect>Areas



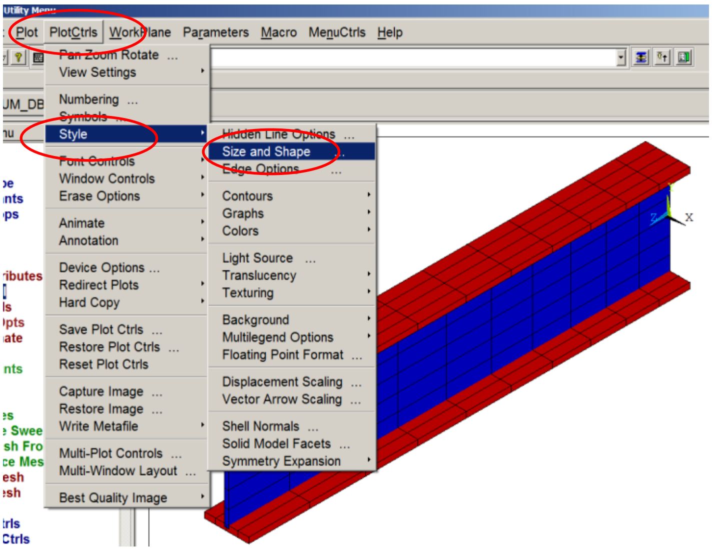
14. Merge geometry: **Preprocessor**>Numbering Ctrls> Merge Items>Keypoints



15. Generate mesh: **Preprocessor**>Meshing>Mesh Tool>Mesh>Areas *(Quad)*



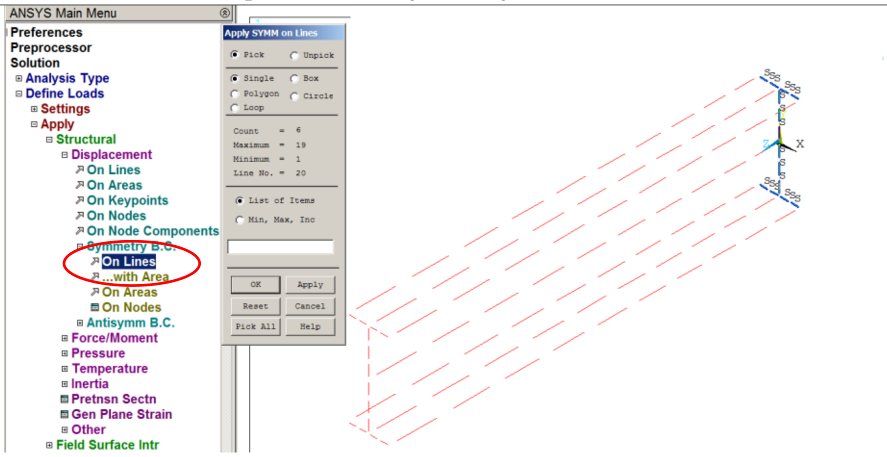
16. Plot elements using thickness description



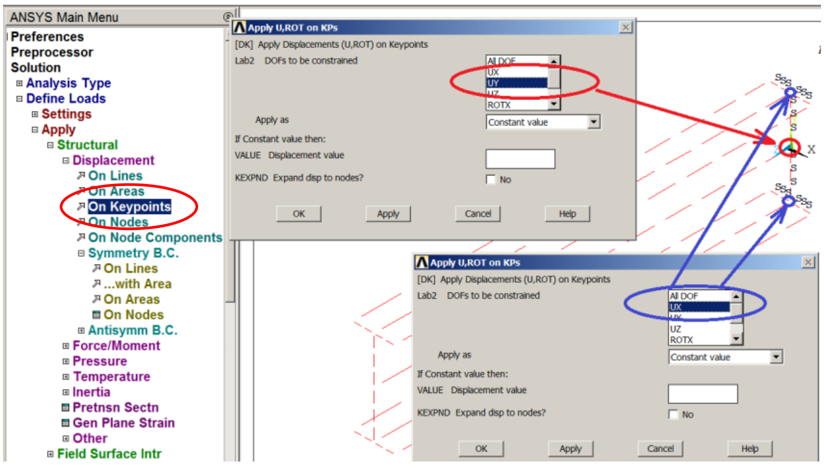
3.2.2. Solution

Define boundary conditions:

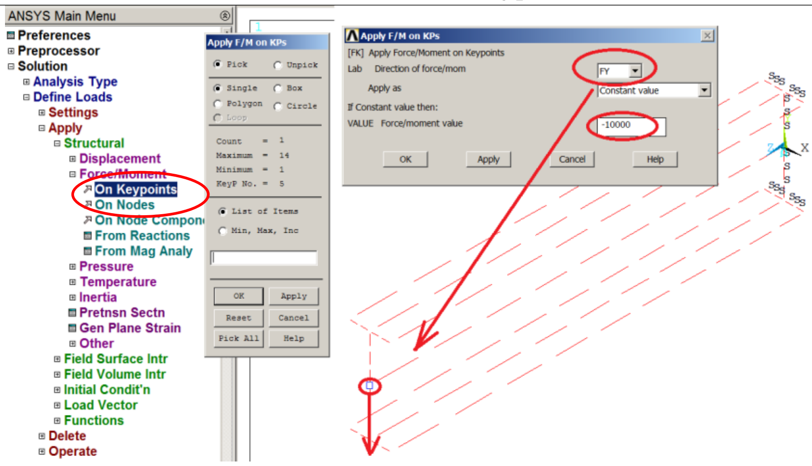
17. Define symmetry B.C. on lines: **Solution**>Define Loads>Apply >Structural>Dispalcements>Symmetry B.C.>On Lines



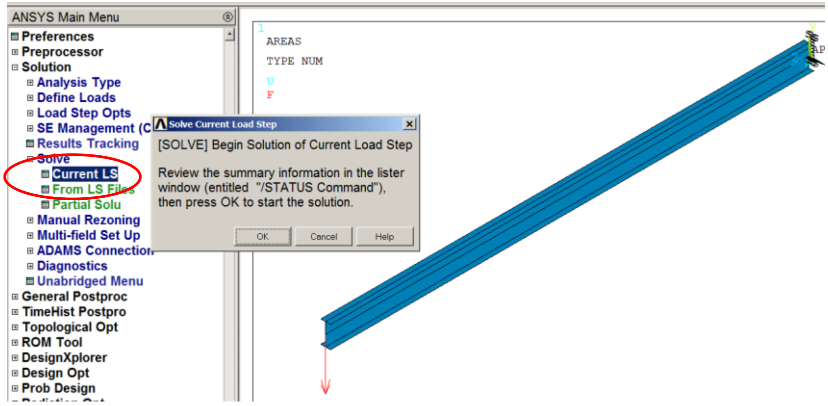
18. Constrain central keypoint on Y (UY=0): **Solution**>Define Loads>Apply >Structural>Dispalcements>On Keypoints



19. Apply concentrated load on keypoint: **Solution**>Define Loads>Apply >Structural>Forces/Moment>On Keypoints



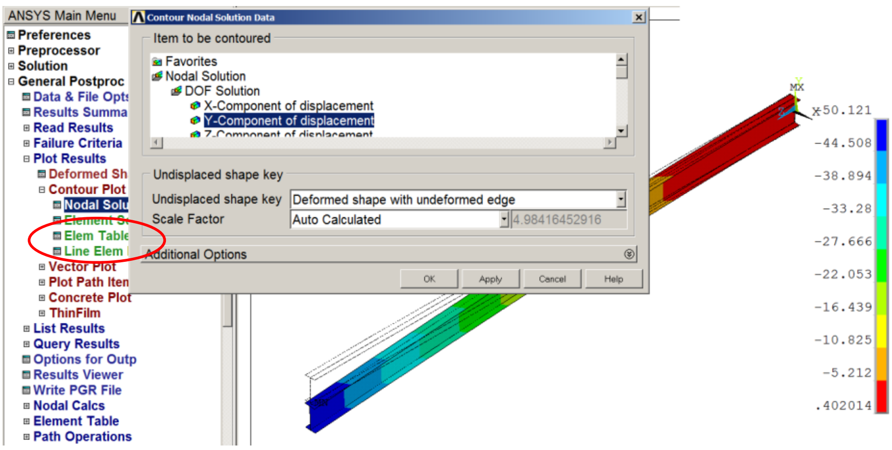
20. Solve the problem: **Solution**>Solve> Current LS



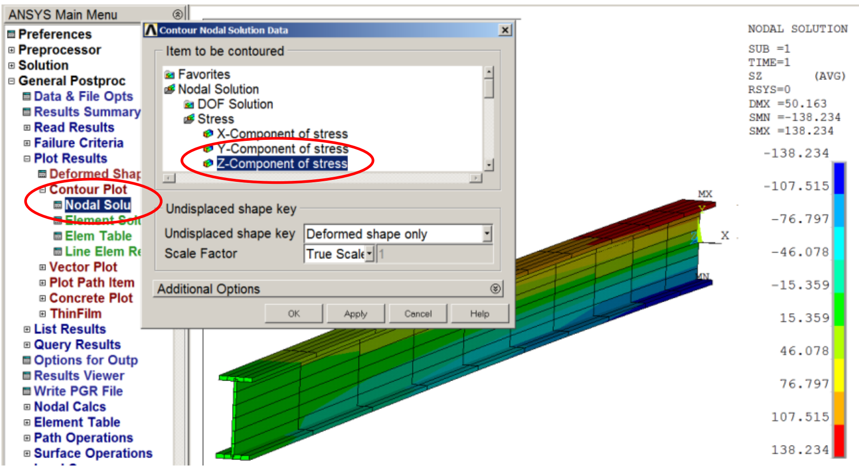
3.2.3. General postprocessor

Show the results as contour maps:
Show displacements i Y (UY), bending stress: normal stress (SZ) and shear stress in the web (SYZ).

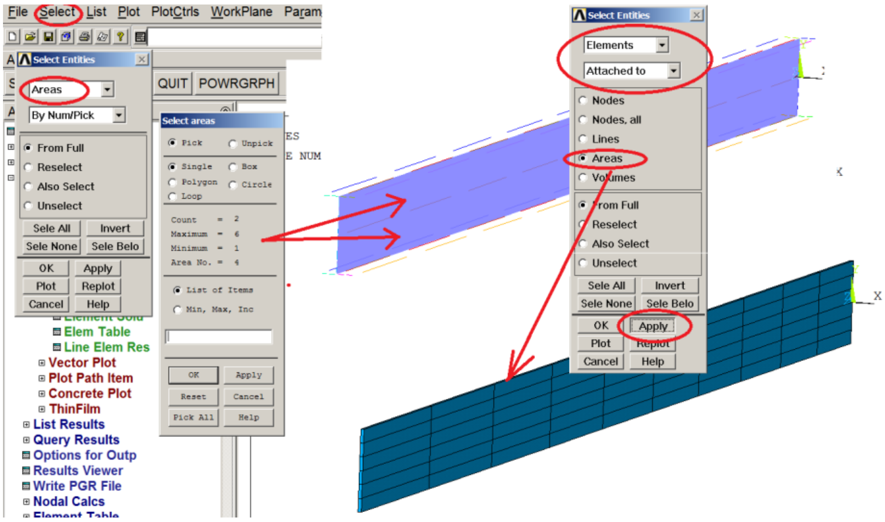
21. Plot displacements in Y (UY)



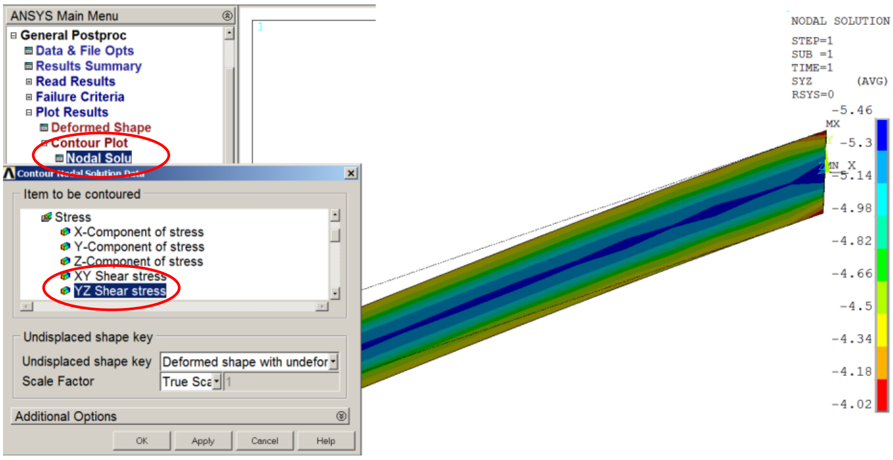
22. Plot normal stress (SZ)



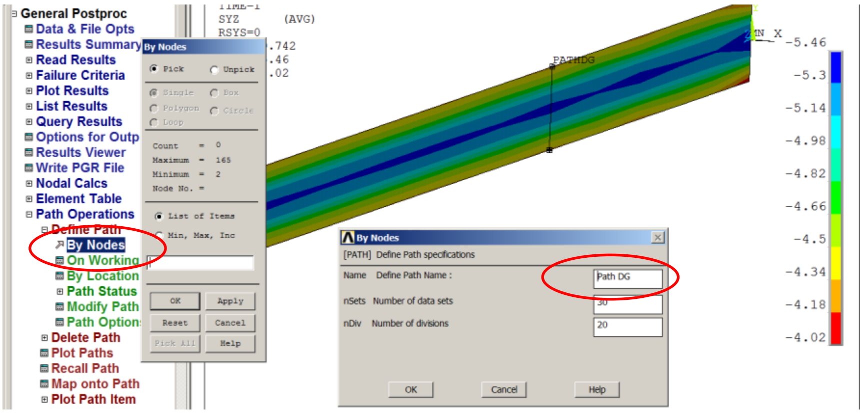
23. Select elements attached to areas *(web elements)*



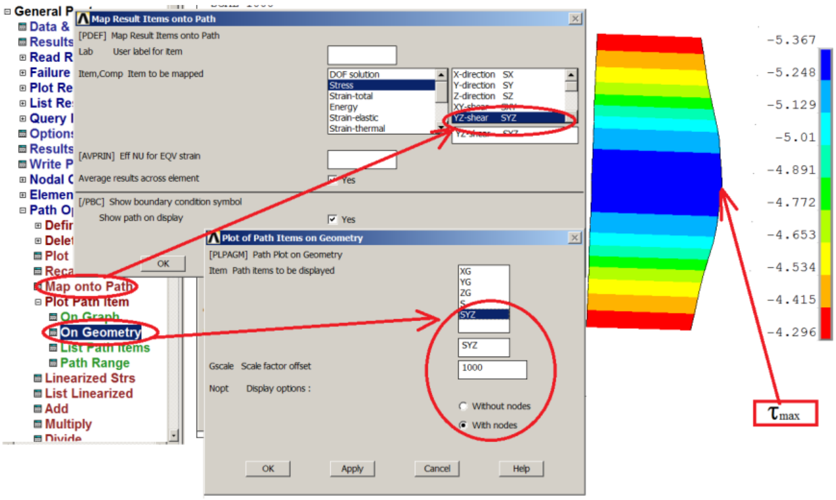
24. Plot shear stress in the web (SYZ)



25. Define path along web height



26. Map shear stress onto path DG and plot shear stress along height of the web *(with nodes)*



4. INTERPRETATION OF THE RESULTS. TASKS TO BE DONE

Solve the problems:

a) Bending of the plate using SHELL181:
- rough mesh with about 20 elements *(ESIZE=30)* (**Model 1a**),
- dense mesh with about 150 elements *(ESIZE=10)* (**Model 1b**),

b) Bending of the thin-walled beam:
- model using 4 noded SHELL181 (**Model 2a**)
- model using 8 noded SHELL281 (**Model 2b**)

Discuss the results.

PLATE	**Model 1a** (SHELL181) rough	**Model 1b** (SHELL181) dense	**BEAM**	**Model 2a** 4 noded (SHELL181)	**Model 2b** 8 noded (SHELL281)
No. of nodes			No. of nodes		
No. of elements			No. of elements		
UZ_{max}			UY_{max}		
SX_{max}			SZ_{max}		
SY_{max}			$SYZ_{max}^{(web)}$		
f_{max}			f_{max}		
σ_x^{max}			σ^G		
σ_y^{max}			σ^D		
			τ_{max}		

Plots needed (should be archived during program session for each model)**:**

For plate:	**for beam**:
1) FE mesh.	1) FE mesh.
2) UZ(x,y)	2) UY(x,y)
3) SX(x,y)	3) SZ(x,y)
4) SY(x,y)	4) SYZ(x,y) in the web
	5) graph: SYZ along DG (point 26)

Final report:
1) Introduction
2) Assumptions for the modeling
3) model description *(solid model, mesh, boundary conditios and loads)*
4) Results
5) Results in the Table
6) Discursion
7) Conclusion