

### Tutorial 3. Plane Frame Analysis

Problem: Determine the displacements and rotations of the nodes, the reaction forces and moments at nodes 1 and 4, and the location and magnitude of the maximum bending stress for the frame shown below (ref. “A First Course in the Finite Element Method, 5<sup>th</sup> edition, Daryl L. Logan, 2012, problem 5.10, p. 302). Assume that the members have a rectangular cross-section of depth,  $b=0.0204$  m, and height  $h=0.4899$  m such that  $A = bh = 1e^{-2} \text{ m}^2$  and  $I_x = bh^3/12 = 2e^{-4} \text{ m}^4$  as specified in the problem. Note that  $I_y = b^3h/12 = 3.47e^{-7} \text{ m}^4$  must be input but, since there is no out of plane bending, does not influence the results. Compare the finite element solution to the text solution given by:

$$u_2 = 0, v_2 = -0.1423e-2 \text{ m}, \phi_2 = -0.5917e-3 \text{ radians}$$

$$u_3 = 0, v_3 = -0.1423e-2 \text{ m}, \phi_3 = 0.5917e-3 \text{ radians}$$

$$F_x^{(1)} = F_x^{(4)} = 0, F_y^{(1)} = F_y^{(4)} = 10,028 \text{ N}, M_1 = 23,276 \text{ N-m}, M_2 = -23,276 \text{ N-m}$$

$$\sigma_{max} = \frac{Mc}{I} = \frac{(23,276 \text{ N-m})(0.2450 \text{ m})}{2e^{-4} \text{ m}^4} = 28.5 \text{ MPa}$$

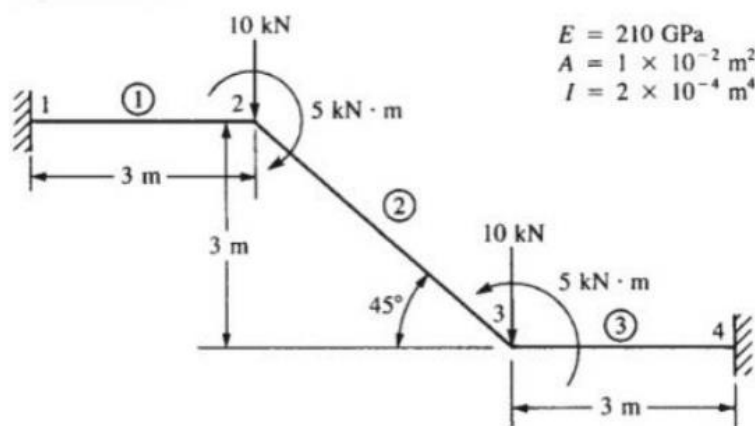


Figure P5-10

#### Finite Element solution

Start => All Programs => Dassault Systems SIMULIA Abaqus => Abaqus CAE => Create Model Database With Standard/Explicit Model  
 File => Set Working Directory => Browse to find desired directory => OK  
 File => Save As => save frame\_tutorial.cae file in Work Directory

### Module: Sketch

Sketch => Create => continue

Add => Line => Connected Line => enter coordinates (0,0), (3,0), (6,-3), (9,-3) right click =>  
Cancel Procedure => Done

### Module: Part

Part => Create => select 2D Planar, Deformable, Wire, Approx size 200 => Continue

Add => Sketch => select 'Sketch-1' => Done => Done

### Module: Property

Material => Create => Name: Material-1, Mechanical, Elasticity, Elastic => set Young's modulus = 210e9, Poisson's ratio = 0.3 => OK

Profile => Create => Generalized => A=1e-2, I<sub>1</sub> = 2e-4, I<sub>12</sub>=0, I<sub>2</sub>=3.47e-7, J=0 => OK

Section => Create => Name: Section-1, Beam, Beam => Continue => Section Integration – Before Analysis => Profile Name: Profile-1 => Linear Properties => E=210e9, G=80.8e9 => Output Points => enter (x<sub>1</sub>, x<sub>2</sub>) = (0,-.245) and (x<sub>1</sub>, x<sub>2</sub>) = (0,.245) => OK

Assign Section => select all elements by dragging mouse => Done => Section-1 => Done => OK

Assign Beam Section Orientation => select full model => Done => n<sub>1</sub> direction = 0.0,0.0,-1.0 => OK => Done

### Module: Assembly

Instance => Create => Create instances from: Parts => Part-1 => Dependent (mesh on part) => OK

### Module: Step

Step => Create => Name: Step-1, Initial, Static, General => Continue => accept default settings => OK

### Module: Load

Load => Create => Name: Step-1, Step: Step 1, Mechanical, Concentrated Force => Continue => select point at (3,0) and (6,-3) => Done => set CF2=-10000 => OK

Load => Create => Name: Step-1, Step: Step 1, Mechanical, Moment => Continue => select point at (3,0) => Done => set CM3= -5000 => OK

Load => Create => Name: Step-1, Step: Step 1, Mechanical, Moment => Continue => select point at (3,0) => Done => set CM3= 5000 => OK

BC => Create => Name: BC-1, Step: Step-1, Mechanical, Displacement/Rotation => Continue => select points at (0,0) and (9,-3) => Done => U1=U2=UR3=0 => OK

### Module: Mesh

Set Model: Model-1, Object => Part: Part-1

Seed => Edges => select entire beam by dragging mouse => Done => Method: By number, Bias: None, Sizing Controls, Number of elements=10 => OK => Done

Mesh => Element Type => select entire truss by dragging mouse => Done => Element Library: Standard, Geometric Order: Linear: Family: Beam, Cubic interpolation (B23)=> OK => Done

Mesh => Part => OK to mesh the part: Yes

#### Module: Job

Job => Create => Name: Job-1, Model: Model-1 => Continue => Job Type: Full analysis, Run Mode: Background, Submit Time: Immediately => OK

Job => Manager => Submit => Job-1

Job => Manager => Results (transfers to Visualization Module)

#### Module: Visualization

Viewport => Viewport Annotation Options => Legend => Text => Set Font => Size=14, Apply to: Legend, Title Block and State Block => OK => OK

View => Graphics Options => Viewport Background = Solid=> Color => White (click on black tile to change background color)

Options => Common => Labels => select 'Show node labels: Black' => OK

Plot => Deformed Shape

Ctrl-C to copy viewport to clipboard => Open MS Word Document => Ctrl-V to paste image

Result => Field Output => select S, Component: S11 => Section Points => Top and Bottom => OK

Plot=> Contours => On Deformed Shape

Report => Field Output => Variable => Position: Unique Nodal => select Spatial displacement: U2: Spatial Displacements, Rotational displacement: UR3 => OK

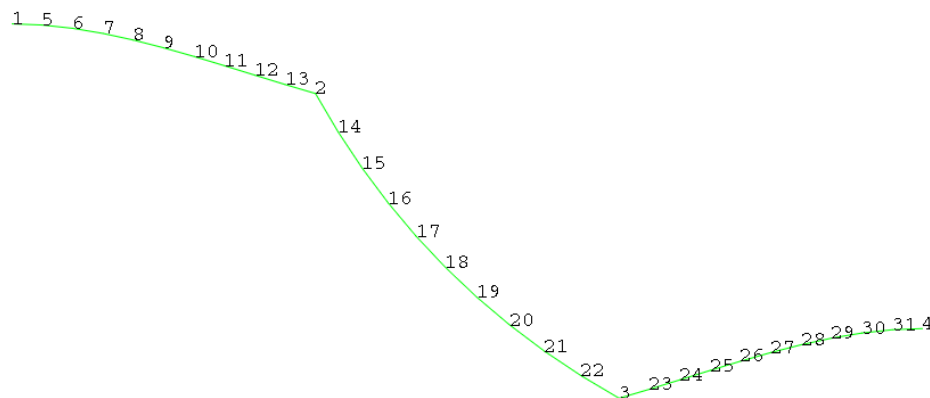
Report => Field Output => Variable => Position: Unique Nodal => select Stress components: S11, Section points - All => OK

Report => Field Output => Variable => Position: Unique Nodal => select Reaction Force: RF, and Reaction Moment: RM3, Section points - All => OK

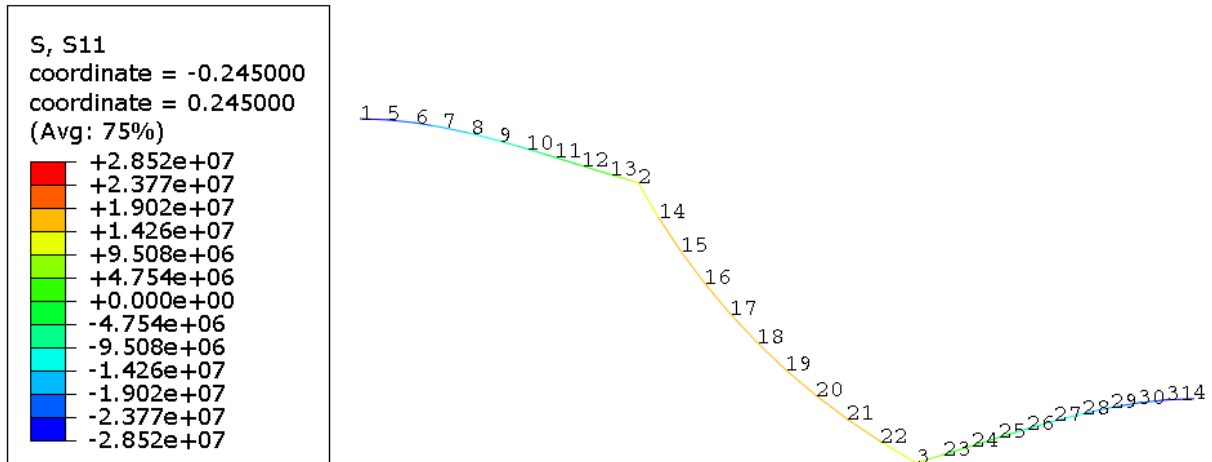
Cut and paste tabulated results from 'Abaqus.rpt' file to MS Word document.

#### Results:

Deformed Shape (node labels turned on)



## Contour plot of bending stress



## Nodal displacements and rotations

Node Label	U.U1 @Loc 1	U.U2 @Loc 1	UR3 @Loc 1
1	568.801E-42	10.00000E-33	23.2843E-33
2	812.574E-15	-1.42331E-03	-591.734E-06
3	-812.576E-15	-1.42331E-03	591.734E-06
4	-568.804E-42	-10.00000E-33	23.2843E-33
5	81.2574E-15	-23.8760E-06	-155.602E-06
6	162.515E-15	-91.2183E-06	-289.775E-06
7	243.772E-15	-195.598E-06	-402.520E-06
8	325.030E-15	-330.588E-06	-493.836E-06
9	406.287E-15	-489.757E-06	-563.724E-06
10	487.544E-15	-666.679E-06	-612.183E-06
11	568.802E-15	-854.924E-06	-639.214E-06
12	650.059E-15	-1.04806E-03	-644.816E-06
13	731.317E-15	-1.23967E-03	-628.989E-06
14	-159.768E-06	-1.58308E-03	-473.387E-06
15	-284.032E-06	-1.70735E-03	-355.040E-06
16	-372.792E-06	-1.79611E-03	-236.693E-06
17	-426.048E-06	-1.84936E-03	-118.347E-06
18	-443.800E-06	-1.86712E-03	9.13088E-12
19	-426.048E-06	-1.84936E-03	118.347E-06
20	-372.792E-06	-1.79611E-03	236.693E-06
21	-284.032E-06	-1.70735E-03	355.040E-06
22	-159.768E-06	-1.58308E-03	473.387E-06
23	-731.318E-15	-1.23967E-03	628.989E-06
24	-650.061E-15	-1.04806E-03	644.816E-06
25	-568.803E-15	-854.924E-06	639.214E-06
26	-487.546E-15	-666.679E-06	612.183E-06
27	-406.288E-15	-489.757E-06	563.724E-06
28	-325.030E-15	-330.587E-06	493.836E-06
29	-243.773E-15	-195.598E-06	402.520E-06

Reaction forces and moments at nodes 1 and 4

Node Label	RF.Magnitude @Loc 1	RF.RF1 @Loc 1	RF.RF2 @Loc 1	RM3 @Loc 1
1	10.E+03	-568.802E-06	10.E+03	23.2843E+03
2	0.	0.	0.	0.
3	0.	0.	0.	0.
4	10.E+03	568.803E-06	10.E+03	-23.2843E+03
5	0.	0.	0.	0.