FEM Computer workshop 1, 2015 (Sep.-Oct.)

Information

The computer workshop should be carried out in groups of two or three students. You will analyze three problems by use of the general purpose finite element program ANSYS during the workshop. After completion of a problem, the results should be presented to and discussed with the instructor of the workshop.

Problem 1. In homework assignment 1 the spring structure shown in Figure 1(a) was analysed. An equivalent structure is shown in Fig. 1(b). There, the springs are replaced by truss elements with tensile stiffness, EA (E is Young's modulus and A is cross sectional area) chosen to match the corresponding spring constants in Fig. 1(b). Analyze the truss structure in Fig. 1(b) by use of ANSYS. The truss elements can be modelled with the element type "LINK180". Before the analysis, E and A should be chosen such that the resulting truss stiffnesses match the springs in HW1. Furthermore, it is convenient to let the external force P be a unit force of 1 N. Carry out the analysis in two steps: (*i*) let $(P_x, P_y) = (1, 0)$ N and (*ii*) $(P_x, P_y) = (0, 1)$ N. Fill in the resulting node displacements in Table 3 below. Does the result agree with your result from homework assignment 1?

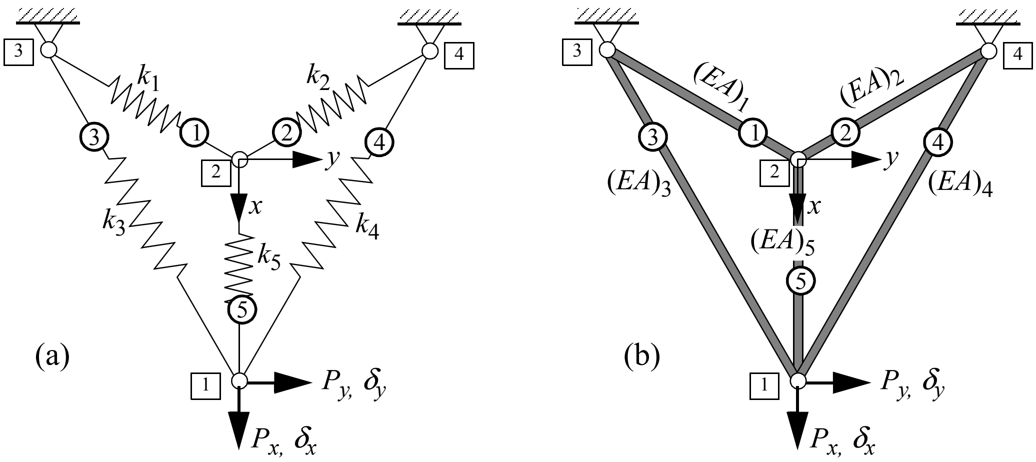


Figure 1. (a) spring structure and (b) truss structure

Node	x/m	y/m
1	1.0	0.0
2	0.0	0.0
3	-0.5	$-\sqrt{3}/2$
4	-0.5	$\sqrt{3}/2$

Table 1. Node coordinates (unit metre).

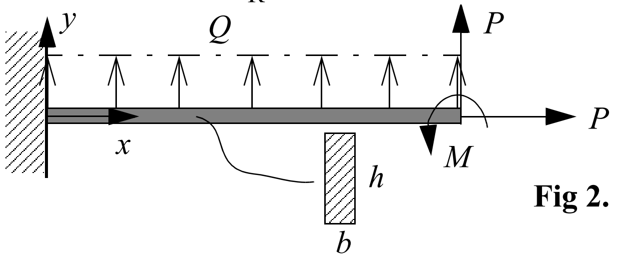
dd	$\frac{k_1}{[\text{N/m}]}$	$\frac{k_2}{[\text{N/m}]}$	$\frac{k_3}{[\text{N/m}]}$	$\frac{k_4}{[\text{N/m}]}$	$\frac{k_5}{[\text{N/m}]}$
01–10	1.0	1.0	3.0	3.0	2.0
11–20	1.0	1.0	3.0	3.0	1.0
21–31	2.0	2.0	1.0	1.0	2.0

Table 2. Spring constants in unit N/m. dd in column one refer to the day in the "personal number" used to determine the model parameters.

Nod	1	2
u_x/m		
u_y/m		

Table 3. Results from analysis with ANSYS.

Problem 2. Analyze the cantilever beam shown in Fig. 2 below. The length of the beam is L = 1 m, and the material is aluminium (Young's modulus E = 70 GPa). The forces applied on the beam, cross sectional data, etc. are shown in Fig. 2. Carry out a FEM analysis with ANSYS, with the beam element "BEAM3". This element is intended for plane frame structures (2D). The element has two nodes with three d.o.f. at each node. The interpolation for the deflection utilizes a third order polynomial and the interpolation for the elongation of the beam makes use of a linear polynomial. Conduct in total three analyses with (*i*) 1 element, (*ii*) 2 elements and (*iii*) 4 elements. Write down the results in Table 4 below, where u_y and θ_z should be evaluated at the nodes, and M_R refer to the reaction moment at the left end of the beam.



Cross section:

h = 6 cm, b = 2 cm

Applied forces:

P = 1 kN, M = 1 kNm, Q = 1 kN

Fig 2.

		1 Element	2 Element	4 Element	Exact solution
$x = \frac{L}{4}$	u_y / mm				2.900
	θ_z / rad				0.02242
$x = \frac{L}{2}$	u_y / mm				10.851
	θ_z / rad				0.04051
$x = \frac{3L}{4}$	u_y / mm				22.846
	θ_z / rad				0.05487
$x = L$	u_y / mm				38.029
	θ_z / rad				0.06614
$x = 0$	M_R / Nm				-2500

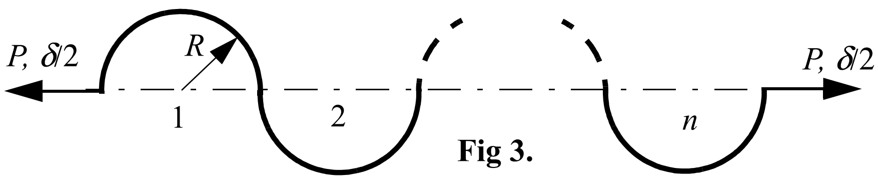
Table 4. Result from analysis with ANSYS

Exact solution:

$$u_y(x) = \frac{QL^3}{24EI}\left(6\left(\frac{x}{L}\right)^2 - 4\left(\frac{x}{L}\right)^3 + \left(\frac{x}{L}\right)^4\right) + \frac{PL^3}{6EI}\left(3\left(\frac{x}{L}\right)^2 - \left(\frac{x}{L}\right)^3\right) + \frac{ML^2}{2EI}\left(\frac{x}{L}\right)^2$$

$$\theta(x) = \frac{QL^2}{6EI}\left(3\frac{x}{L} - 3\left(\frac{x}{L}\right)^2 + \left(\frac{x}{L}\right)^3\right) + \frac{PL^3}{2EI}\left(2\frac{x}{L} - \left(\frac{x}{L}\right)^2\right) + \frac{ML^2}{EI}\frac{x}{L}$$

Problem 3. Determine the spring constant k ($=P/\delta$) for the linear elastic structure shown in Fig 3. The structure consists of n number of curved beams of semicircular shape, where each semicircle has a mean radius R and a circular cross section with radius r. The deformation of the structure is primarily due to bending. Carry out the analysis with ANSYS by use of the beam element "BEAM3". Choose r/R = 0.1. Note that if the symmetry of the structure is utilized, the stiffness k can be calculated for an arbitrary number of semicircles n. In fact a crude estimate can be obtained with only one beam element, how? Carry out the analysis with a gradually increasing number of beam elements. Compare your answer with the analytical solution given in Fig. 3. How many beam elements are needed in order to reduce the difference (error) between the FEM solution and the analytical solution to less than 2%?



$$k = \frac{2EI}{n\pi R^3}$$

Fig 3.