Benchmark Example No. 42

Thick Circular Plate

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The user of the program is solely responsible for the applications. We strongly encourage the user to test the correctness of all calculations at least by random sampling.
1 Problem Description

The problem consists of a circular plate with a constant area load, as shown in Fig. 1. The system is modelled as a plane problem and the deflection in the middle of the plate is determined for various thicknesses [1].

2 Reference Solution

Depending on the various thicknesses of the plate, the maximum deflection \( w \) in the middle of the plate can be obtained as \( w = w_B + w_S \), where \( w_B \) is the displacement due to bending and \( w_S \) is the displacement due to shear strains, determined as follows [2]:

\[
w_B = \frac{p \cdot r^4 (5 + \mu)}{64 \cdot K (5 + \mu)} \tag{1}
\]

\[
K = \frac{E \cdot h^3}{12(1 - \mu^2)} \tag{2}
\]
Thick Circular Plate

\[ ws = \frac{1.2 \cdot p \cdot r^2}{4 \cdot G \cdot h} \]  \hspace{1cm} (3)

where \( p \) is the load ordinate, \( r \) the radius, \( E \) the elasticity modulus, \( h \) the plate thickness, \( \mu \) the Poisson’s ratio and \( G \) the shear modulus.

The maximum bending moment at the middle of the plate is independent of the plate thickness and corresponds for the specific load case to

\[ M_x = M_y = \frac{p \cdot r^2}{16} \cdot (3 + \mu) = 4928.125 \text{ [kNm/m]} \]  \hspace{1cm} (4)

3 Model and Results

The properties of the model are defined in Table 1. The plate is modelled as a plane system with three degrees of freedom, \( u_z, \phi_x, \phi_y \), per node and \( u_z \) hinged at the edge, as shown in Fig. 1. The weight of the system is not considered. A constant area load \( p = 1000 \text{ kN/m}^2 \) is applied, as shown in Fig. 1. The system is modelled with 1680 quadrilateral elements, as presented in Fig. 2, and a linear analysis is performed for increasing thicknesses. The results are presented in Table 2 where they are compared to the analytical solution calculated from the formulas presented in Section 2 and the influence of the varying thickness is assessed.

Table 1: Model Properties

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>Geometric Properties</th>
<th>Loading</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E = 3000 \text{ kN/cm}^2 )</td>
<td>( h = 0.5 - 2.5 \text{ m} )</td>
<td>( p = 1000 \text{ kN/m}^2 )</td>
</tr>
<tr>
<td>( G = 1300 \text{ kN/cm}^2 )</td>
<td>( r = 5 \text{ m} )</td>
<td></td>
</tr>
<tr>
<td>( \mu = 0.154 )</td>
<td>( D = 10 \text{ m} )</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: FEM model
The maximum bending moment is calculated at the middle of the plate, as \( M_x = M_y = 4932.244 \text{[kNm/m]} \) with a deviation of 0.08%.

| \( h \) [m] | \( h/D \) | Analytical \( u_z \) [mm] | SOF. \( u_z \) [mm] | \(|e_r|\) [%] |
|---|---|---|---|---|
| 0.50 | 0.05 | 137.413 | 137.440 | 0.02 |
| 1.00 | 0.10 | 17.609 | 17.618 | 0.05 |
| 1.50 | 0.15 | 5.431 | 5.437 | 0.11 |
| 2.00 | 0.20 | 2.418 | 2.421 | 0.14 |
| 2.50 | 0.25 | 1.321 | 1.324 | 0.23 |

Figure 3: Displacements

4 Conclusion

The example allows the verification of the calculation of thick plates. It has been shown, that the calculated results are in very good agreement with the analytical solution even for thicker plates.

5 Literature
