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Benchmark Example No. 12

Cantilever in Torsion

SOFiSTiK | 2024

**VERiFiCATION
BE12 Cantilever in Torsion**

VERiFiCATION Manual, Service Pack 2024-4 Build 27

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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.

Front Cover

6th Street Viaduct, Los Angeles Photo: Tobias Petschke

Overview

Element Type(s):	B3D
Analysis Type(s):	STAT, GNL
Procedure(s):	
Topic(s):	
Module(s):	ASE
Input file(s):	torsion.dat

1 Problem Description

The problem consists of a cantilever beam as shown in Fig. 1. The tip of the cantilever is offsetted in y -direction by $\Delta_y = l/200 = 2.5 \text{ cm}$, creating a geometrical imperfection. The beam is loaded with a transverse force P_z and an axial force P_x . The imperfection acts as a lever arm for the loading, causing a torsional moment. The torsional moment at the support with respect to the local and global coordinate system is determined.

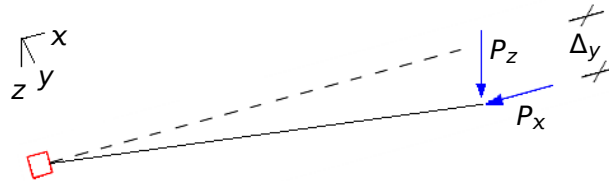


Figure 1: Problem Description

2 Reference Solution

In order to account for the effect of the geometrical imperfection on the structure, second-order theory should be used, where the equilibrium is established at the deformed system. According to the equilibrium of moments at the deformed system, with respect to the global x -axis, the torsional moment at the support $M_{x_{global}}$ is:

$$M_{x_{global}} = P_z (u_y + \Delta_y) - P_x u_z, \quad (1)$$

whereas by the local x -axis the torsional moment $M_{x_{local}}$ is:

$$M_{x_{local}} = P_z u_y + P_x \left(\frac{\Delta_y}{l} \right) u_z, \quad (2)$$

where l is the length of the beam, Δ_y the initial geometrical imperfection and P_x is negative for compression.

3 Model and Results

The properties of the model [1] [2] are defined in Table 1. A standard steel material is used as well as a standard hot formed hollow section with properties according to DIN 59410, DIN EN 10210-2. A safety

factor $\gamma_M = 1.1$ is used, which according to DIN 18800-2 it is applied both to the yield strength and the stiffness. Furthermore, the self weight, the shear deformations and the warping modulus C_M are neglected. At the support the warping is not constrained.

Table 1: Model Properties

Material Properties	Geometric Properties	Loading
S 355	$l = 5 \text{ m}$	$P_z = 10 \text{ kN}$
$\gamma_M = 1.1$	RRo/SH 200 × 100 × 10 [3]	$P_x = 100 \text{ kN}$
$C_M = 0$	$\Delta_y = 2.5 \text{ cm}$	

Table 2: Results

	u_y	u_z	$M_{xglobal}$	M_{xlocal}	P_{buck}
	[cm]	[cm]	[kNcm]	[kNcm]	[kN]
SOF.	3.209	10.204	57.08	26.98	163.7
Ref.[4]	3.20	10.2	57.0	26.9	164

The corresponding results are presented in Table 2. Figure 2 shows the deformed shape of the structure and the nodal displacements for the z and y direction. From the presented results, we can observe that the values of the moments are correctly computed. Here has to be noted that the reference results are according to [1], where they are computed with another finite element software, and not with respect to an analytical solution.

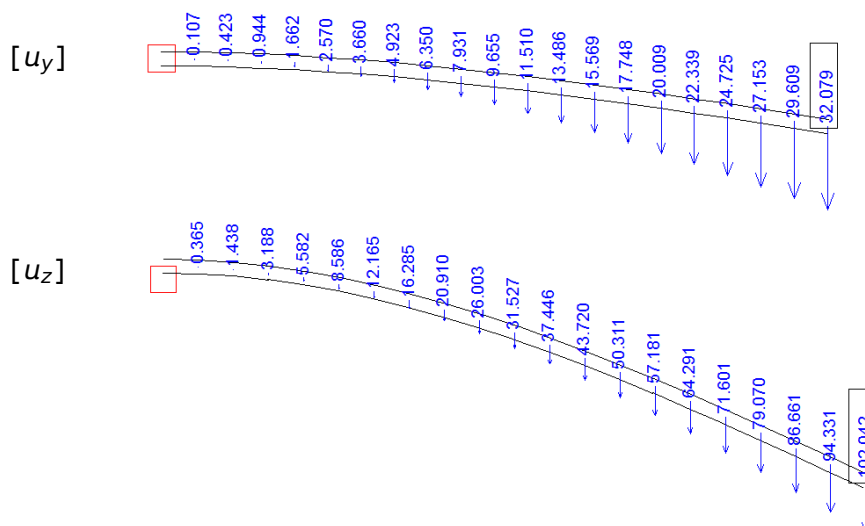


Figure 2: Deformations [mm]

4 Conclusion

This example presents a case where torsion is induced to the system because of an initial geometrical imperfection. It has been shown that the behaviour of the beam is captured accurately.

5 Literature

- [1] V. Gensichen and G. Lumpe. *Zur Leistungsfähigkeit, korrekten Anwendung und Kontrolle räumlicher Stabwerksprogramme*. Stahlbau Seminar 07.
 - [2] V. Gensichen. *Zur Leistungsfähigkeit räumlicher Stabwerksprogramme, Feldstudie in Zusammenarbeit mit maßgebenden Programmherstellern*. Stahlbau Seminar 07/08.
 - [3] K. Holschemacher. *Entwurfs- und Berechnungstabeln für Bauingenieure*. 3rd. Bauwerk, 2007.
 - [4] V. Gensichen and G. Lumpe. "Zur Leistungsfähigkeit, korrekten Anwendung und Kontrolle von EDV-Programmen für die Berechnung räumlicher Stabwerke im Stahlbau". In: *Stahlbau 77 (Teil 2)* (2008).
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