Benchmark Example No. 40

Portal Frame

SOFiSTiK | 2024

VERiFiCATiON
BE40 Portal Frame

VERiFiCATiON Manual, Service Pack 2024-4 Build 27

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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):	frame.dat

1 Problem Description

The problem consists of a rigid rectangular frame, with an imperfection at the columns, subjected to a uniform distributed load q across the span and to various single loads, as shown in Fig. 1. For the linear case, the structure is subjected to the uniform load only, whereas for the nonlinear case, all defined loads including the imperfection are considered. The response of the structure is determined and compared to the analytical solution.

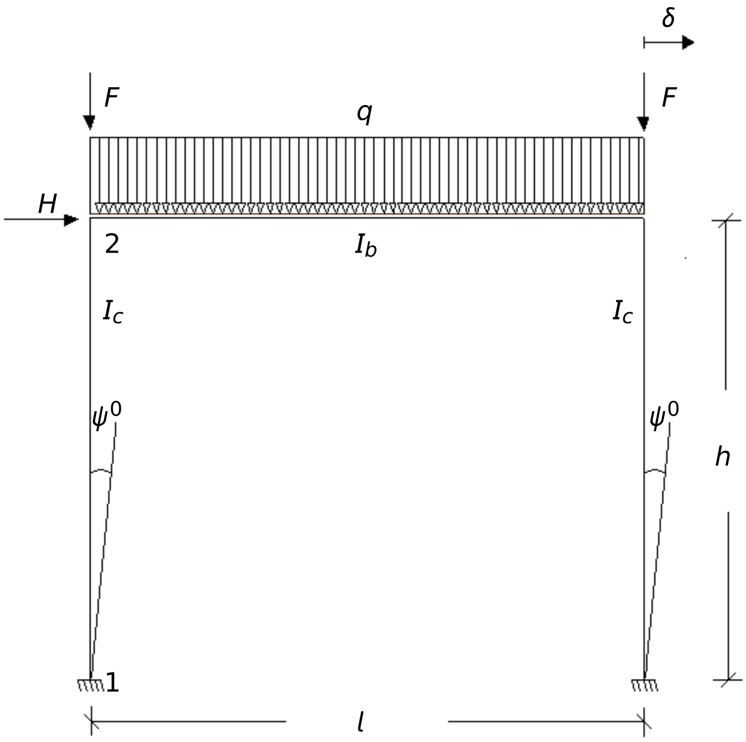

Figure 1: Problem Description

2 Reference Solution

For the linear case, where only the distributed load is considered, the moments M are determined in terms of the shear force H as follows:

$$H_1 = H_2 = \frac{ql^2}{4h(k+2)} \tag{1}$$

$$M_1 = M_2 = \frac{Hh}{3} \tag{2}$$

$$M_3 = M_4 = M_1 - H_1 h \tag{3}$$

where $k = I_b h \,/\, I_c l$. For the nonlinear case, in order to account for the effect of the normal force and the imperfections on the determination of the resulting forces and moments, second order theory has to be used. The moments at nodes $1-4$ are determined in dependency of the column characteristic ratio $\epsilon = l_c \sqrt{N/EI_c}$, giving the influence of the normal force $N = F + ql/2$ with respect to the column properties, length l_c and bending stiffness EI_c. Further information on the analytical formulas can be found in Schneider [1].

3 Model and Results

The properties of the model are defined in Table 1. The frame has an initial geometrical imperfection at the columns of linear distribution $\psi_0 = 1/200$, with a maximum value of $25\ mm$ at nodes 3 and 4. The normal force N, used to determine ϵ, is calculated to be $430\ kN$ at the columns and the ratio $\epsilon = 1.639$. For the linear case the results are presented in Table 3 and they are compared to the analytical solution calculated from the formulas presented in Section 2. For the nonlinear case, the results are presented in Table 2 and they are compared to the reference example provided in Schneider [1].

Table 1: Model Properties

Material Properties	Geometric Properties	Loading
$EI_c = 6000\ kNm^2$	$l = 6\ m$	$q = 10\ kN/m$
$EI_b = 4000\ kNm^2$	$h = 5\ m$	$H = 20\ kN$
	$\psi_0 = 1/200$	$F = 400\ kN$

Table 2: Nonlinear Case Results

	Ref. [1]	SOF.
$M_1\ [kN\,m]$	38.2	38.62
$M_2\ [kN\,m]$	22.5	22.52
$M_3\ [kN\,m]$	58.1	58.02
$M_4\ [kN\,m]$	58.8	58.79
$\delta\ [mm]$	65.3	65.44

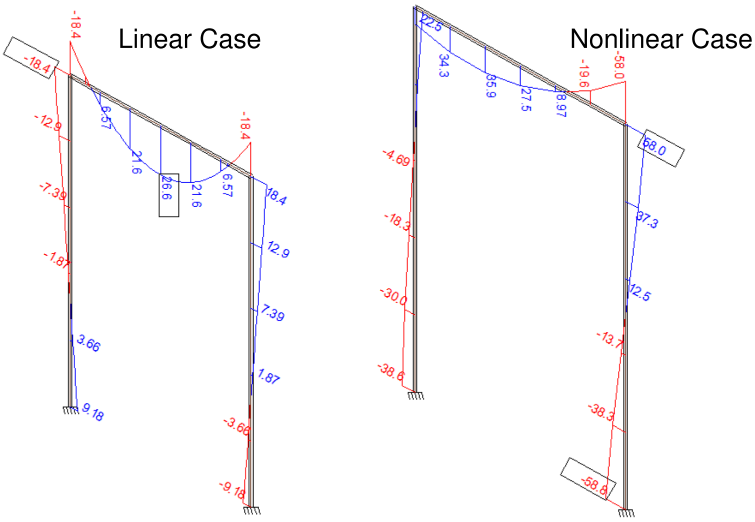

Figure 2: Bending Moments

Table 3: Linear Case Results

	Ref. $[Sect.2]$	SOF.
$H_1 = H_2$ $[kN]$	5.54	5.52
$M_1 = M_2$ $[kN\,m]$	9.23	9.18
$M_3 = M_4$ $[kN\,m]$	18.46	18.43

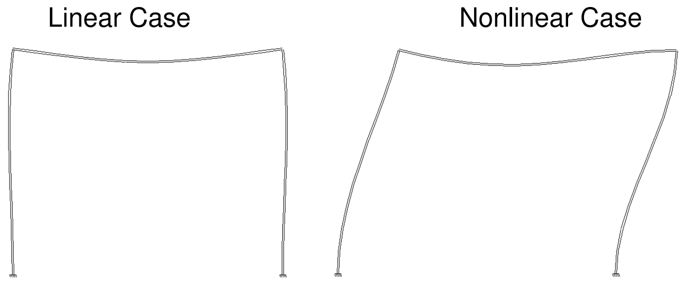

Figure 3: Deformed Shape

4 Conclusion

This example examines a rigid frame under different loading conditions. It has been shown that the behaviour of the structure is captured accurately for both the linear and the nonlinear analysis.

5 Literature

[1] Schneider. *Bautabellen für Ingenieure*. 19th. Werner Verlag, 2010.