SDND103 - Column subjected to an axial dynamic stress

Abstract

It acts to calculate the response of a column subjected to an unspecified seismic loading. The column is modelled by an undamped spring-mass system, its connection with the soil by a non-linearity of type force - displacement.

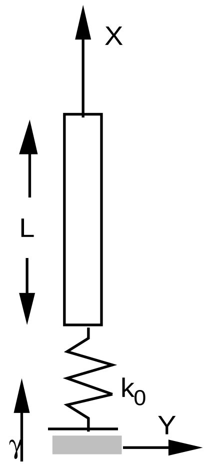
One tests the discrete element in traction and compression, the computation of the eigen modes and the computation of the transient response by modal recombination with taking into account of a non-linearity of type force-displacement. The initial velocity is taken non-zero and the loading is of standard acceleration imposed on the ground.

The got results are in very good agreement with the results of reference which are analytical results.

1 Problem of reference

1.1 Geometry

the system consists of a column resting on the soil and subjected to a seismic request. It is modelled by a mass, its connection with the soil by a spring k_0 whose behavior model translates a non-linearity of type force-displacement.



Characteristics of the column:

length: $L=2\ m$;
section: $S=0{,}3\,m^2$.

1.2 Properties of the materials

Masses column: $m=450\ kg$.
Stiffness of the come out from connection: $k_0=10^5\,N/m$.

1.3 Boundary conditions and loadings

Boundary conditions

only authorized displacements are the translations according to the axis X : $dy=dz=0$.

The corrective force F_c due to nonthe linearity of the soil is defined by the following relation:

$F_c(x)=\dfrac{f(x_{seuil})}{x_{seuil}}-f(x)$ with, if $x>x_{seuil}$, $f(x)=k_0\left[1-\dfrac{|x|}{x_0}\right]x$

One takes $x_{seuil}=10^{-6}\,m$, $k_0=10^5\,N/m$ and $x_0=0{,}1\,m$.
One thus imposes under key word RELA_EFFO_DEPL of operator DYNA_VIBRA the function:

$F_c(x)=\dfrac{k_0}{x_0}x.[|x|-x_{seuil}]$

Loading

the soil is subjected to an acceleration $\gamma(t)$ in the direction x , is built so that the displacement of the spring-mass system is sinusoidal $x=a.sin(\omega t)$ with $a=0{,}01$ and $\omega=\pi/4$.

1.4 Initial conditions

In an initial state, the system is released of its equilibrium position with a velocity v_0 : with $t=0$ $dx(0)=0$ $v_0=dx/dt(0)=a.\omega$.

2 Reference solution

2.1 Method of calculating used for the reference solution

This test is developed in detail in the reference [bib1].

The fundamental equation of the dynamics, moving relative motion of the spring-mass system compared to the soil is written: $\ddot{x}+\frac{k(x)}{m}x=\gamma(t)$.

For a displacement of the form $x=a.sin(\omega t)$ and $\ddot{x}=-a\omega^2\sin(\omega t)$, one obtains from the equation of motion the shape of the accelerogram:

$$\gamma(t)=a\sin(\omega t)\left[-\omega^2+\frac{k_0}{m}\left(1-\frac{|a\sin(\omega t)|}{x_0}\right)\right]$$

The fundamental frequency f_0 of the undamped oscillator is worth $f_0=\frac{1}{2\pi}\sqrt{\frac{k_0}{m}}$.

2.2 Results of reference

fundamental Frequency f_0 of the undamped oscillator.
Displacements relating to times 2,6,10,14 and 18 seconds.

2.3 Uncertainty on the solution

No if one calculates the integral of Duhamel analytically [bib2].

2.4 Bibliographical references

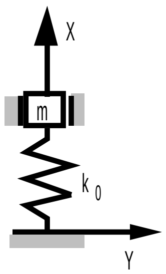
1.P. LALUQUE, P. LABBE, S. PETETIN and A. TIXIER: Seismic response of a building engine PWR1300 by taking account of separation enters the foundation and the soil. Note SEPTEN TA83.06 (May 1984).

2.J.S. PRZEMIENIECKI: Theory of matrix structural analysis. New York, Mac Graw-Hill, 1968, p. 351-357.

3 Modelization A

3.1 Characteristic of the modelization

the spring-mass system is modelled by a discrete element DIS_T.



Numerical data:

for the spring-mass system: $m = 450\ kg$
for the soil: $k_0 = 10^5\ N/m$
for non-linearity: $x_0 = 0{,}1\ m$; $a = 0{,}01$ and $\omega = \pi/4$.

Temporal integration is carried out with the algorithm of Eulerian or the algorithm of Devogelaere and time step of 0,02 second. Computations are filed all time step.
One considers a null ξ_i reduced damping for all the calculated modes.

3.2 Characteristics of the mesh

The mesh consists of a node and a mesh of the type POI1.

3.3 Quantities tested and results

One checks the eigenfrequency of the oscillator as well as displacements relative of the node $NO1$ to various times (for the algorithm of integration EULER).

Frequency (Hz)	Reference
	2,37254

relative Displacement of the node $NO1$ with the algorithm of numerical integration of Eulerian:

Time (S)	Reference
2	0,01
6	– 0,01
10	0,01
14	– 0,01
18	0,01

relative Displacement of the node $NO1$ with the algorithm of numerical integration of Devogelaere:

Time (S)	Reference

2	0,01
6	– 0,01
10	0,01
14	– 0,01
18	0,01

4 Summary of the results

One notes very a good agreement with the analytical solution (error lower than $0{,}01\%$).