

Modeling of Newton's cradle to illustrate time history analysis with large displacements

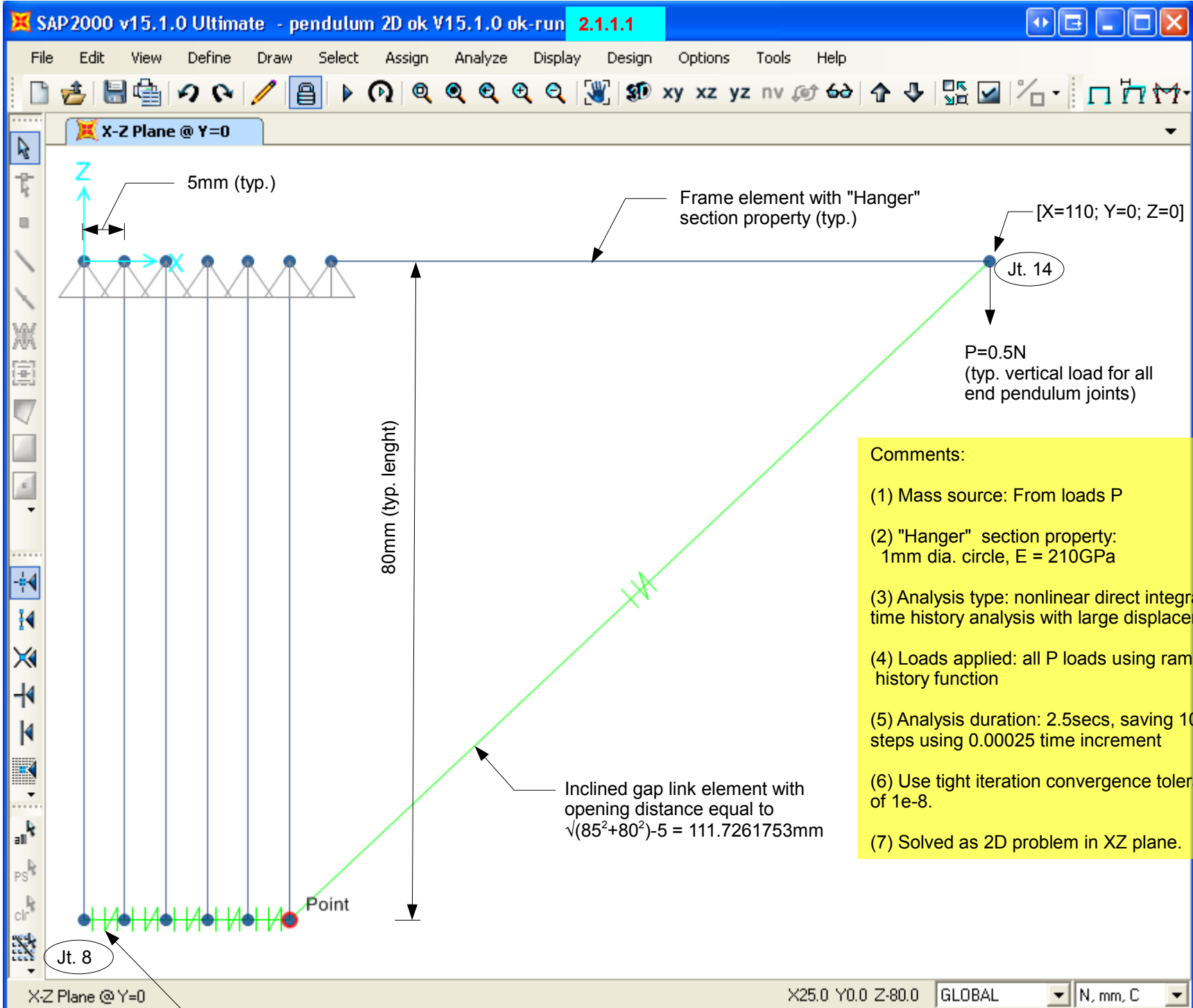
Program: SAP2000
Version: 15.1.0
Date: 1/25/2013
Author: ok

Model versions: run2.1.1.1

Purpose

- Illustrate capability of SAP2000 to handle large displacements in time history analysis.
- Model contact between individual pendulum mass joint using gap link elements.

Model Description



Horizontal gap link element with zero opening distance (typ.)

Time function

Time History Function Definition

Function Name

Define Function

Time	Value
0.	0.
0.	0.
0.25	1.
10.	1.

Function Graph

Properties of the time history load case

SAP2000 v15.1.0 Ultimate - pendulum 2D ok V15.1.0 ok-run2.1.1.1 no springs

Load Case Data - Nonlinear Direct Integration History

Load Case Name: TH Set Def Name Modify/Show...

Notes:

Load Case Type: Time History Design...

Initial Conditions:

- ☒ Zero Initial Conditions - Start from Unstressed State
- ☐ Continue from State at End of Nonlinear Case

Important Note: Loads from this previous case are included in the current case

Modal Load Case: Use Modes from Case MODAL

Loads Applied:

Load Type	Load Name	Function	Scale Factor
Load Pattern	P	RAMP	1.
Load Pattern	P	RAMP	1.

Add Modify Delete

☐ Show Advanced Load Parameters

Time Step Data:

Number of Output Time Steps: 10000

Output Time Step Size: 2.500E-04

Time History Motion Type:

- ☒ Transient
- ☐ Periodic

Other Parameters:

Damping: Proportional Damping Modify/Show...

Time Integration: Hilber-Hughes-Taylor Modify/Show...

Nonlinear Parameters: User Defined Modify/Show...

OK Cancel

Mass and Stiffness Proportional Damping

Damping Coefficients:

	Mass Proportional Coefficient	Stiffness Proportional Coefficient
<input checked="" type="radio"/> Direct Specification	0.	0.
<input type="radio"/> Specify Damping by Period		
<input type="radio"/> Specify Damping by Frequency		

	Period	Frequency	Damping
First			
Second			

Recalculate Coefficients

OK Cancel

Note small size of time step.

Time Integration Parameters

Method

☐ Newmark

Gamma

Beta

☐ Wilson

Theta

☐ Collocation

Gamma

Beta

Theta

☒ Hilber - Hughes - Taylor

Gamma

Beta

Alpha

☐ Chung and Hulbert

Gamma

Beta

Alpha

Alpha-m

OK Cancel

Nonlinear Parameters

Material Nonlinearity Parameters

☒ Frame Element Tension/Compression Only

☒ Frame Element Hinge

☒ Cable Element Tension Only

☒ Link Gap/Hook/Spring Nonlinear Properties

☒ Link Other Nonlinear Properties

☐ Time Dependent Material Properties

Solution Control

Maximum Substep Size

Minimum Substep Size

Maximum Constant-Stiff Iterations per Step

Maximum Newton-Raphson Iter. per Step

Iteration Convergence Tolerance (Relative)

Use Event-to-event Stepping

Event Lumping Tolerance (Relative)

Max Line Searches per Iteration

Line-search Acceptance Tol. (Relative)

Line-search Step Factor

Reset To Defaults

OK Cancel

Time time integration method and its parameters
and tight iteration convergence tolerance.

Properties of gap link elements

Link/Support Property Data

Link/Support TypeGap

Property NameGap0Set Default Name

Property NotesModify/Show...

Total Mass and Weight

Mass0Rotational Inertia 10

Weight0Rotational Inertia 20

Rotational Inertia 30

Factors For Line, Area and Solid Springs

Property is Defined for This Length In a Line Spring1

Property is Defined for This Area In Area and Solid Springs1

Directional Properties

Direction	Fixed	NonLinear	Properties
<input checked="" type="checkbox"/> U1	<input type="checkbox"/>	<input checked="" type="checkbox"/>	Modify/Show for U1...
<input type="checkbox"/> U2	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for U2...
<input type="checkbox"/> U3	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for U3...
<input type="checkbox"/> R1	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for R1...
<input type="checkbox"/> R2	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for R2...
<input type="checkbox"/> R3	<input type="checkbox"/>	<input type="checkbox"/>	Modify/Show for R3...

Fix AllClear All

P-Delta Parameters

Advanced...

OKCancel

Link/Support Directional Properties

Identification

Property NameGap0

DirectionU1

TypeGap

NonLinearYes

Properties Used For Linear Analysis Cases

Effective Stiffness200

Effective Damping0

Properties Used For Nonlinear Analysis Cases

Stiffness200

Open0

OKCancel

Discussion of Results

- The animated video of deformed shape with a scale factor of 1 shows that the model is behaving as expected.