Dynamic loading imposed on structure by lowering a mass via a pulley assembly

Tutorial

Name:	Dynamic loading imposed on structure by lowering a mass via a pulley assembly
Description:	Modeling of pulley assembly with the primary goal of applying the pulley assembly loads to the structure.
Program:	SAP2000
Version:	17.2.0
Model ID:	580

The goal of this tutorial is to illustrate modeling of dynamic loading originating from lowering a mass via a pulley assembly.

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Purpose

The primary goal of this tutorial is to illustrate how to model dynamic loading originating from a pulley assembly depicted in Figure 1.

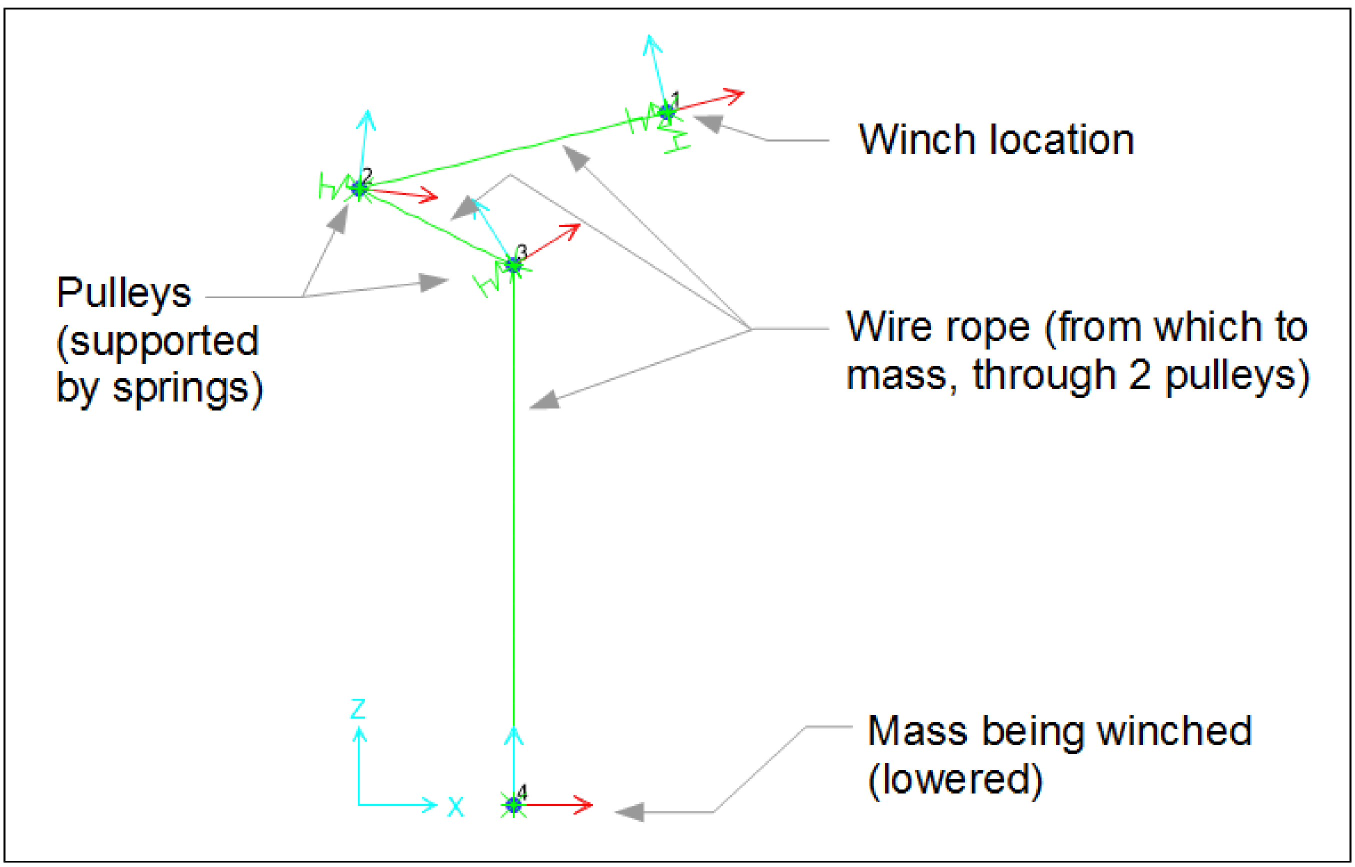

Figure 1: Geometry of the pulley assembly

Initially, the entire the pulley assembly is at rest and the mass at joint 4 is being supported by a cable going through two pulleys and attached to the winch located at joint 1.

Winching (lowering) of the mass using a constant speed (1ft/sec) of the winch and the associated dynamic effects will be modeled. The dynamic effects will take place primarily at the beginning and the end of the winching operation when the speed of the winch changes from 0ft/sec to 1ft/sec and vice versa.

Model Description

The modeling is based on the following assumptions:

- The qualitative response is the primary focus and therefore no specific dimensions and properties are shown in Figure 1. If needed, these properties can be obtained directly from the attached model file.
- The cable is not being modeled as moving over the pulleys. Instead, it is directly connected to the pulleys (joints 2 and 3) represented as springs which model the flexibility of the supporting structure. These springs resist load normal to the cable at the middle point of contact, but not tangentially. The local axes of the joints are chosen to bisect the angle between the cable segments entering and leaving the pulley. There is no consideration of the radius of the pulley except to locate the middle point of contact.
- Winching (lowering of the mass) is modeled by applying deformation load to the vertical cable. This moves the mass downward. Dynamical behavior of the mass is captured. Dynamics of the cable itself is not, since it is resumed to be insignificant.
- Load case "Payout NL" is used to increase the deformation load of the vertical cable linearly in time, which would correspond to a constant speed of winching. The "Payout NL" load case uses time function "Payout start" at the beginning and the end of the winching to smooth the response to eliminate high frequencies in the results. This corresponds to the behavior of the actual structure for which the winching would start and stop with a gradual increase or decrease of speed.
- Since the model utilizes only cable elements which inherently include P-Delta and large-displacement effects, it is not necessary to specify these effects in the definition of the "Payout NL" load case. However, nonlinear direct-integration time-history is required to capture cable nonlinearity. A nonlinear static load case is used as initial conditions to apply dead load before beginning the winching operation.

Discussion of Results

The analysis results are presented in Figures 2 to 5.

Figures 2 to 4 show the displacement, velocity and acceleration of the the mass being lowered vs. time and they clearly indicate that the model is able to correctly capture lowering of the mass using a constant speed of 1ft/sec. Except for the regions at the beginning and the end of the lowering operation which are affected by dynamic effects, the displacement decreases linearly, the speed is constant and the acceleration is zero.

Figure 5 shows the forces in the vertical cable and the feeder cable that is connected to the winch. These cable forces are consistent with the mass displacement, velocity and acceleration plots. Note that the tension in the cable decreases somewhat during winching due to damping forces that are resisting part of the load. These forces will act on the supporting structure, which is a primary goal of the analysis.

Results will be sensitive to the damping assumed and to the shape of the transitions at the start and end of winching, so sensitivity studies may be warranted.

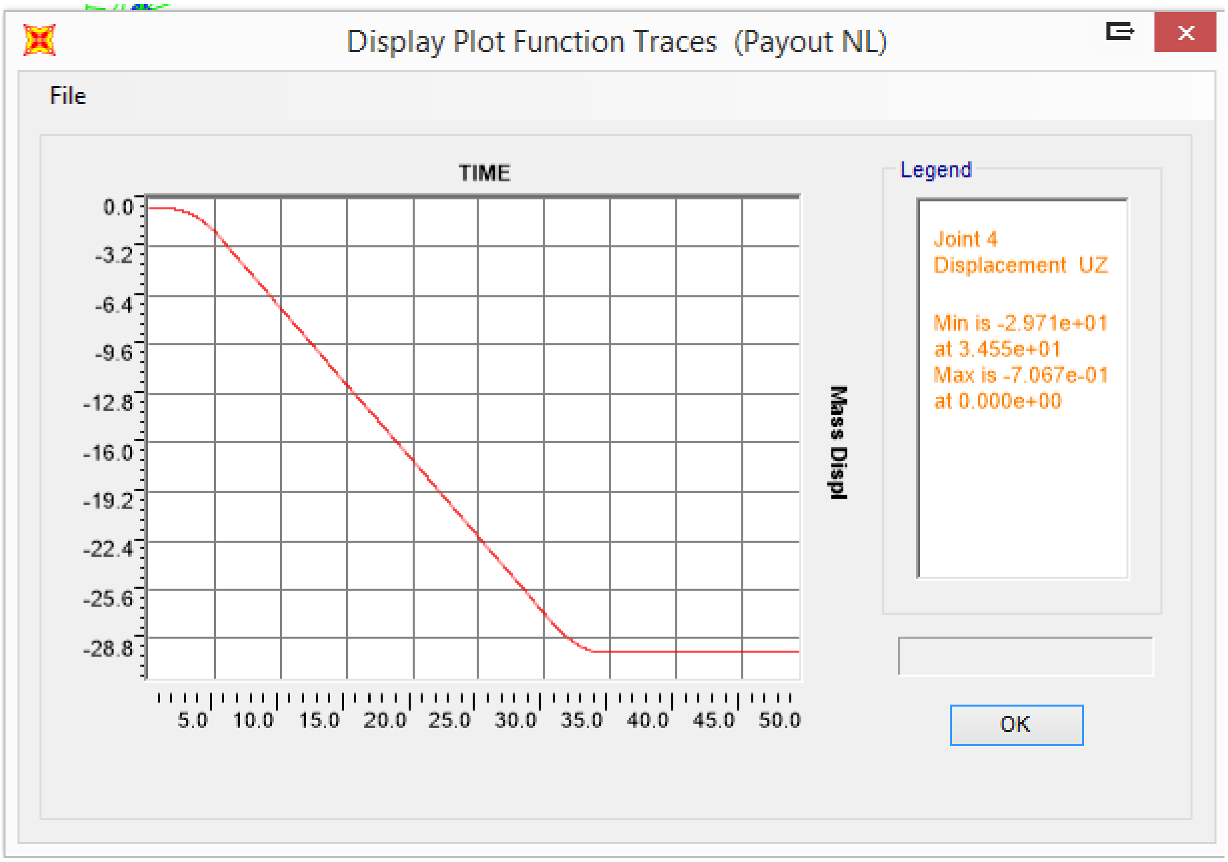

Figure 2: Mass displacement

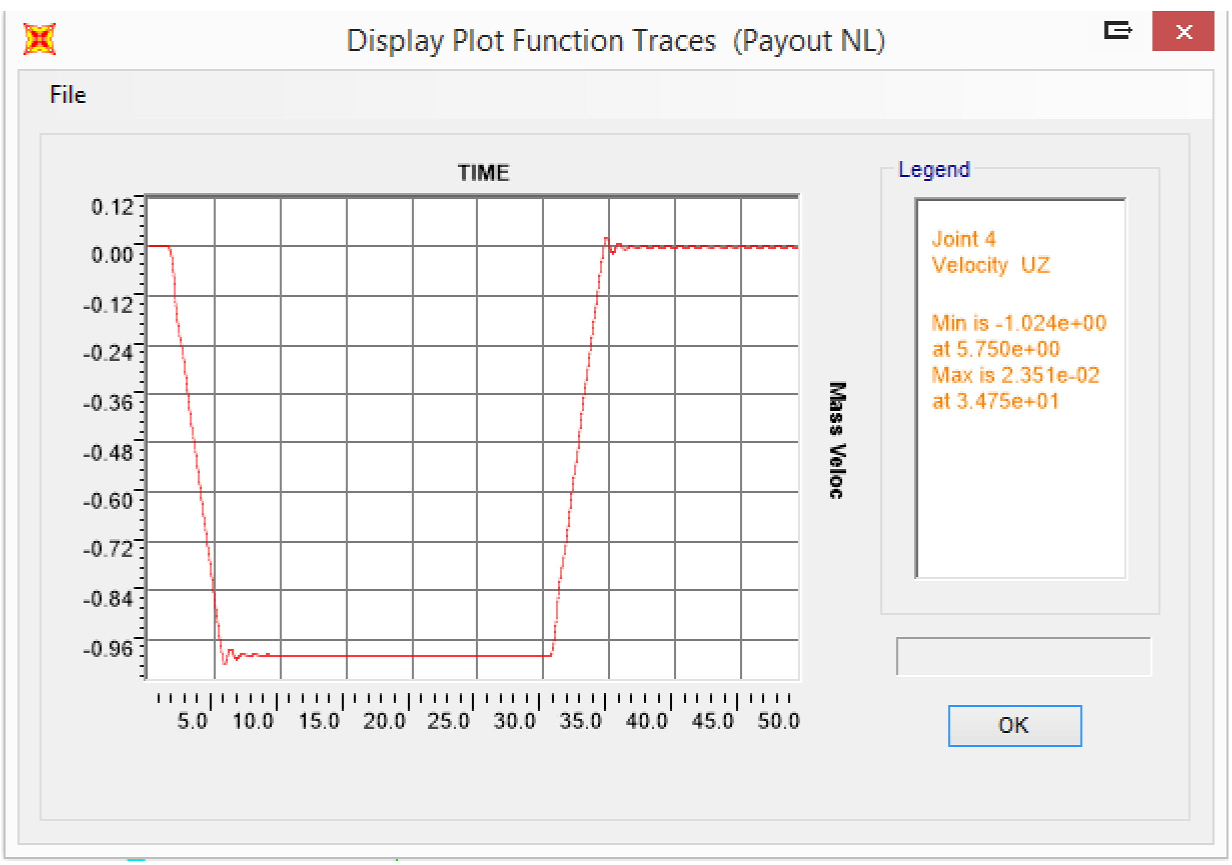

Figure 3: Mass velocity

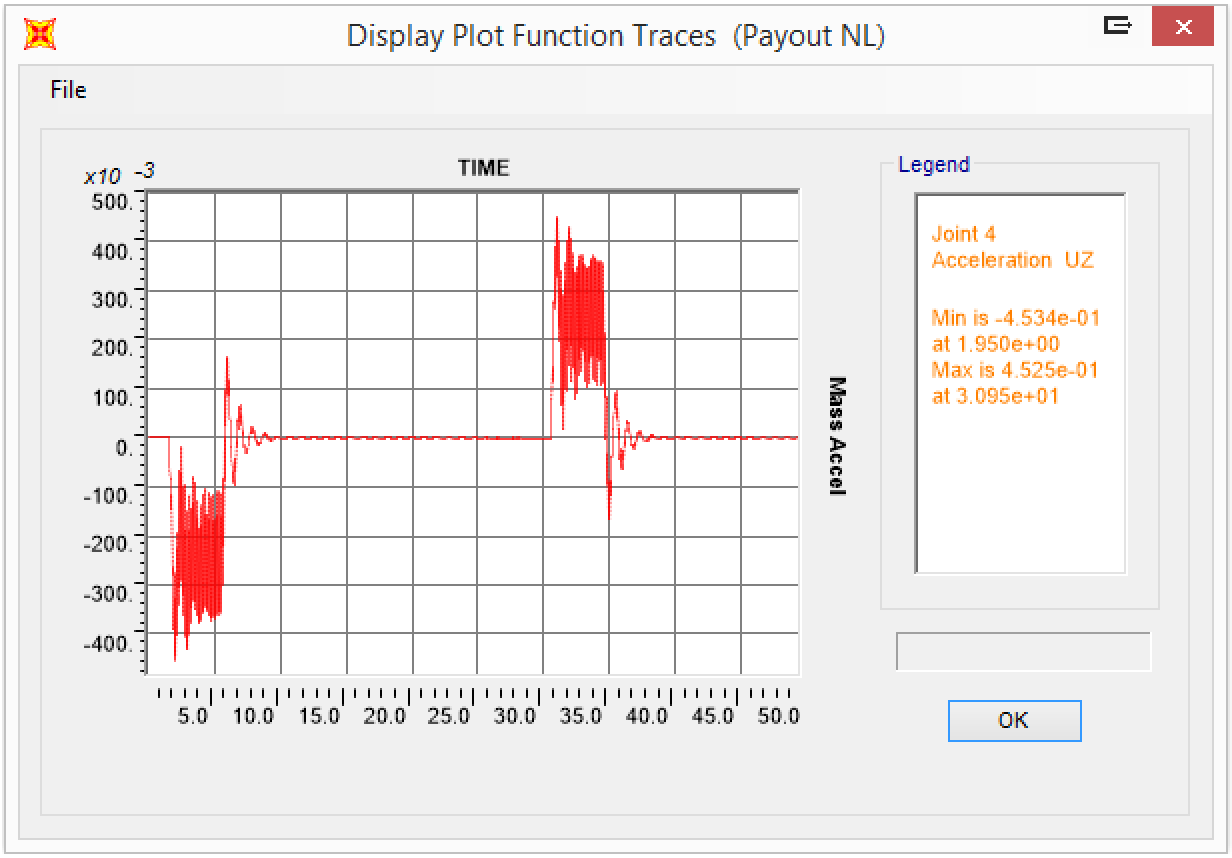

Figure 4: Mass acceleration

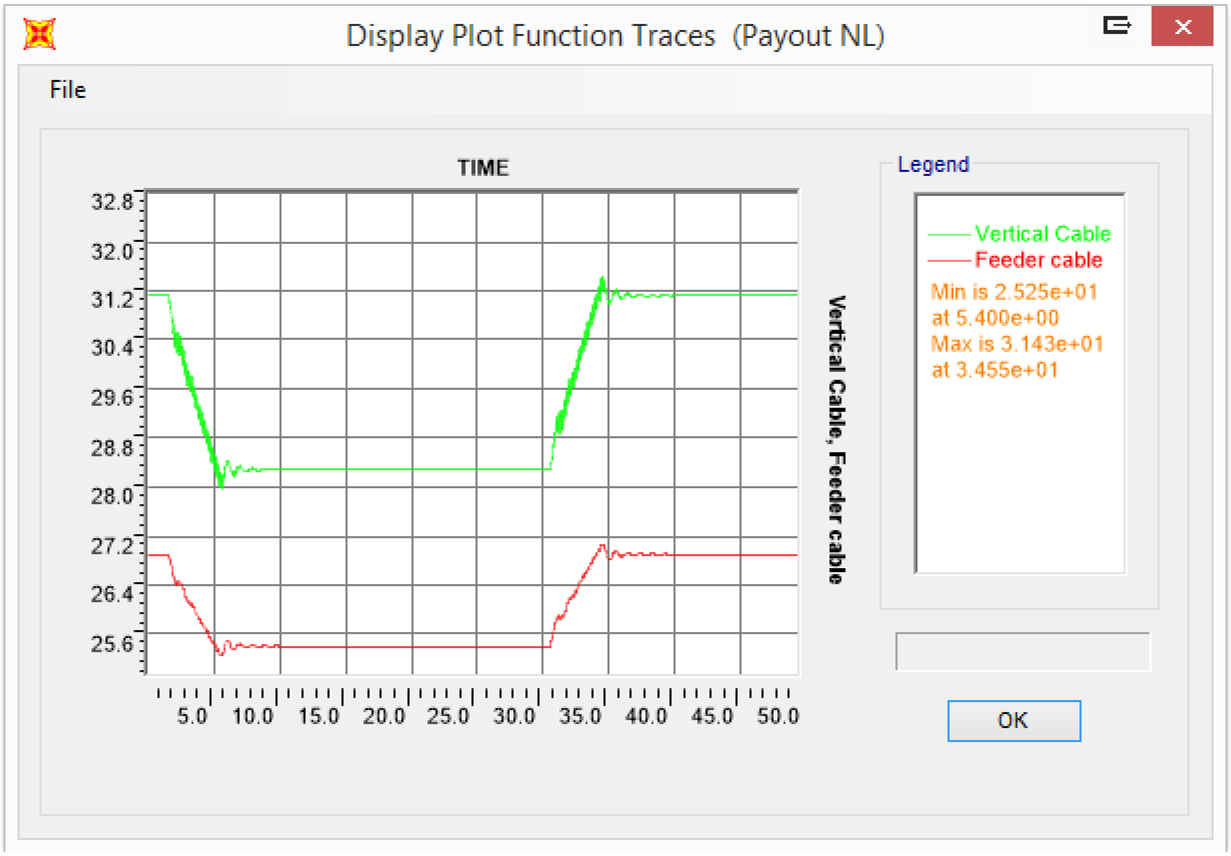

Figure 5 Cable forces

Attachments

- Zipped SAP2000 V17.2.0 model