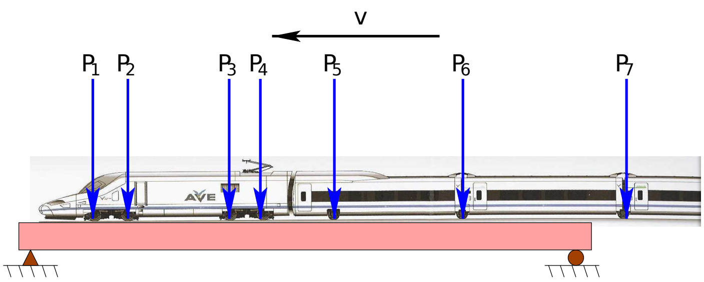
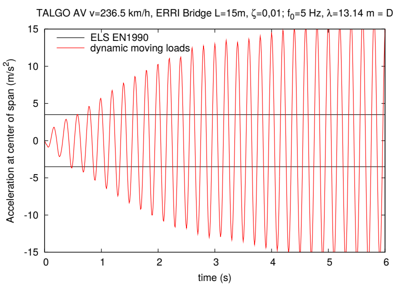
Technical University of Madrid
School of Civil Engineering
Group of Computational Mechanics

# CALDINTAV 3.0

## A program for dynamic calculation of railway bridges




USER'S MANUAL

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# 1 Introduction

## 1.1 Summary and Scope

CALDINTAV is a program for the dynamic calculation of railway bridges developed in MATLAB and PYTHON languages by the Computational Mechanics Group of the Technical University of Madrid, Spain.

The objective is to be able to perform fast calculations in the time domain including hundreds or thousands of scenarios, for fast dynamic compatibility checks of trains.

CALDINTAV program can determine the dynamic displacement and acceleration in time domain at the mid-span of the simply-supported bridges under the moving loads or interaction model. This program is able to perform a parametric calculation for different trains and for a range of train velocity.

This document explains how to use the GUI version of CALDINTAV program and how to introduce the input data for the dynamic calculation.

## 1.2 Development

CALDINTAV originates from the PhD of J. Dominguez. An user-friendly version was developed later and put in the public domain. Subsequently, a more complete version which includes statically skew bridges and statically redundant structures has been developed and is used currently for research purposes.

The CALDINTAV version described in this manual is ultimate version, including different type of bridges: simply-supported bridge, portal frame bridge, multi-span bridge and vehicle-bridge dynamic interaction model.

## 1.3 What's new in CALDINTAV v3.0

This version has major changes with respect to CALDINTAV v1.0 and v2.0 that are listed as following:

- A totally new GUI of CALDINTAV is designed.
- Different distributions for different OS are available.
- Different types of bridges are also included.
- The skewness of the bridges is introduced in this version.
-

## 1.4 Requirements

### 1.4.1 Windows

### 1.4.2 Linux

CALDINTAV v3.0 requires the instalation of Python and some additional packages: numpy, scipy, sympy, matplotlib, joblib, PyQt4. Those packages will be checked if are already installed during the installation of CALDINTAV.

### 1.4.3 Max OS

## 1.5 How to install CALDINTAV v3.0

### 1.5.1 Installing in Windows

### 1.5.2 Installing in Linux

CALDINTAV is a normal Python package. The installer file can be downloaded from our website. Once the download is done, it is easy to install the program using the **pip** command as following:

```
pip install caldintav.tar.gz
```

May be you need to be supervisor in order to install the program.

### 1.5.3 Installing in Mac OS

## 1.6 How to run CALDINTAV v3.0

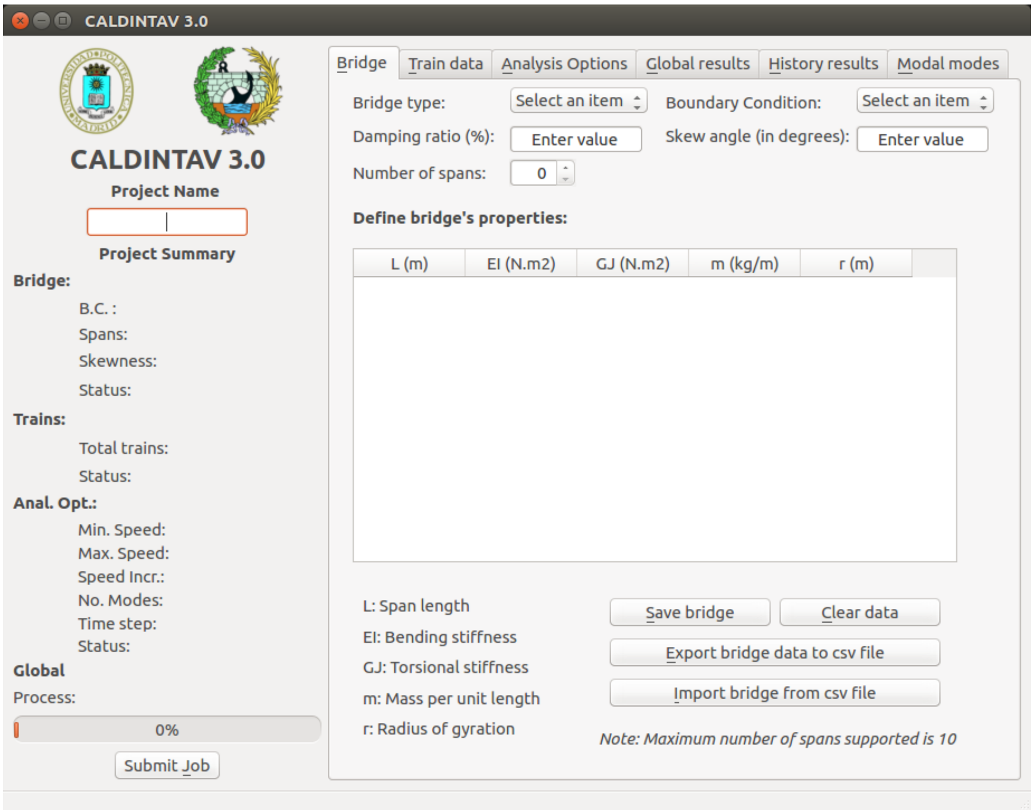



Figure 1: GUI of CALDINTAV

#### 1.6.1 Running in Windows

#### 1.6.2 Running in Linux

#### 1.6.3 Running in Mac OS

### 1.7 How to report bugs

# 2 Structure of program CALDINTAV v3.0

# 3 Using CALDINTAV for dynamic analysis of railway bridges

In order to perform a dynamic calculation with CALDINTAV, firstly the name of project should be introduced as indicated in Fig. 2 and then the following types of data are needed to be defined:

- Data for the bridge
- Data for trains that are used in the calculation
- Options for the dynamic analysis: method, train speed, time increment, number of modes, etc.

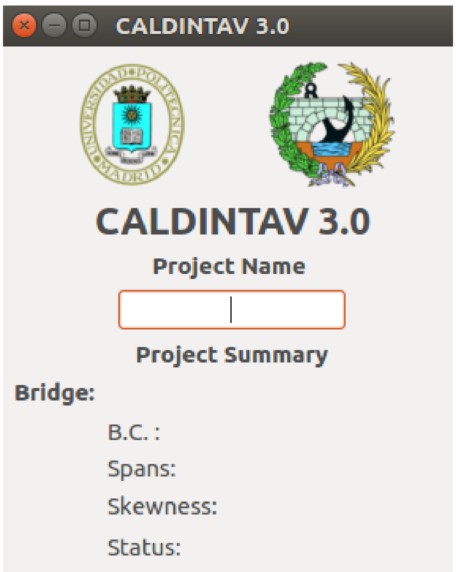



Figure 2: Introducing the name of the project

## 3.1 Definition of bridge data

The definition of the properties of the bridge is realized in the tab "Bridge", in which the bridge type, boundary condition, damping ratio, skewness, number of spans and mechanical properties of the cross section should be defined as shown in Fig. 3. The following procedure is recomended to introduce the bridge data:

1. For the bridge type, there are three types of bridge structures that are supported in this version of CALDINTAV: single span, portal frame and multi-span bridges. To select the bridge type, it is just only to click on the select item at the right side and a small window will appear as shown in Fig. 1 that contains all the described options.

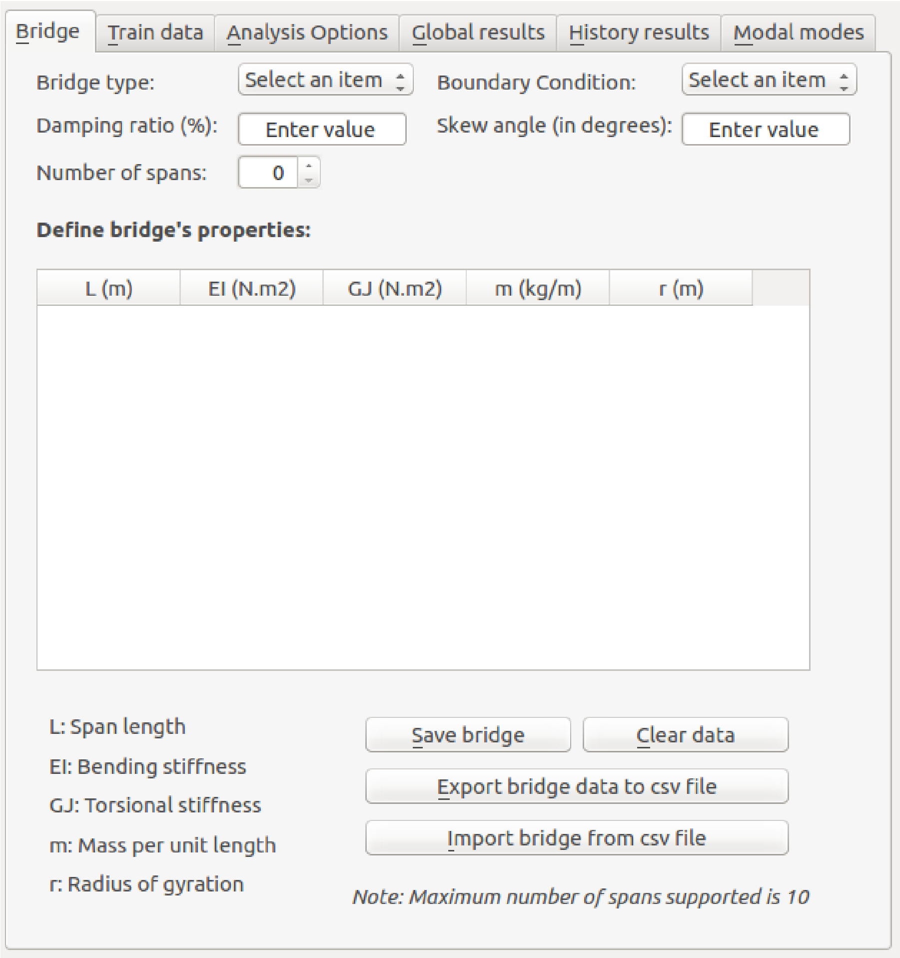



Figure 3: “Bridge” Tab in GUI of CALDINTAV

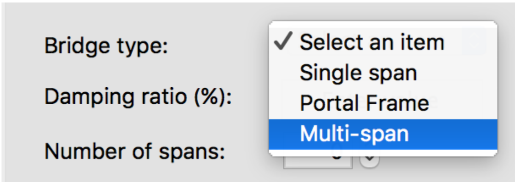
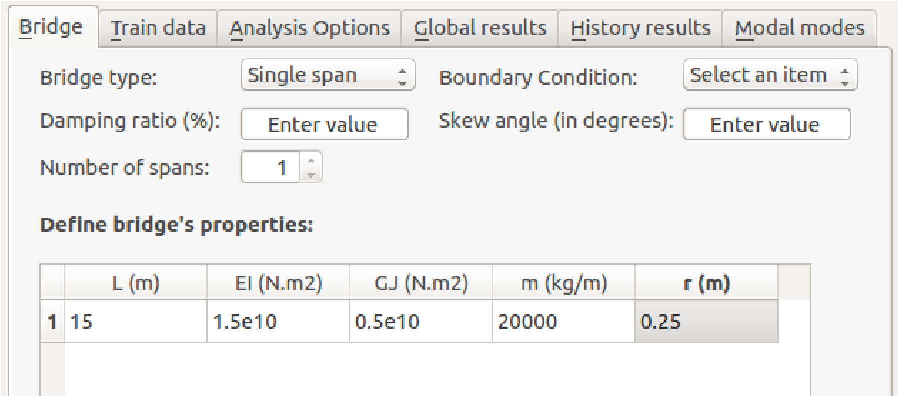



Figure 4: Selecting options in bridge type

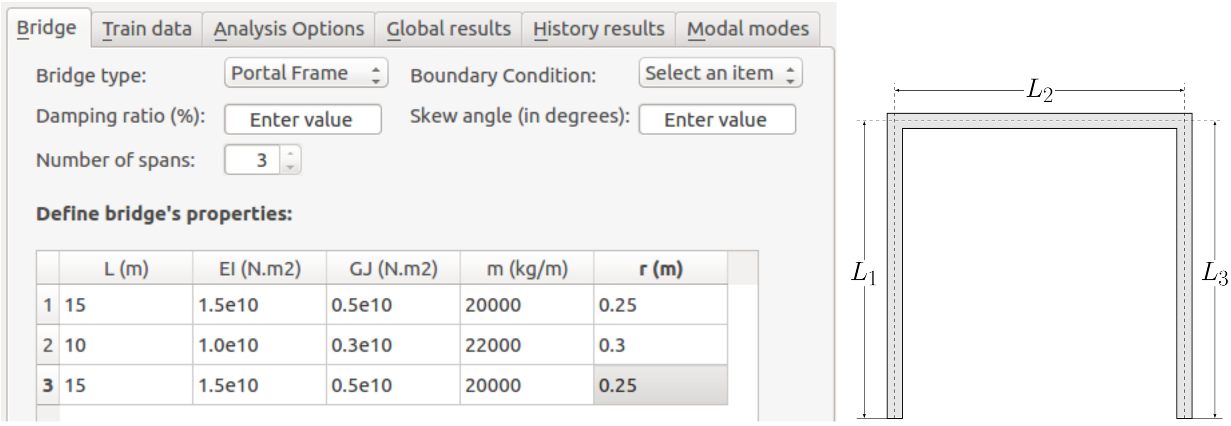
- In the case that the single span is selected, the number of spans is automatically defined as 1 and can't be changed, and therefore in the table of the bridge's properties there is only one row to be appeared. The required properties of the bridge for the span are span length (L), bending stiffness (EI), torsional stiffness (GJ), mass per unit length (m) and the radius of gyration (r). (See Fig. 5)
- In the case that the portal frame is selected, the number ot spans is automatically defined as 3 and can't be changed and therefore in the table of the bridge's properties there are three rows to be appeared in order to define the properties of each span. (See Fig. 6)
- In the case that the multi-span bridge is selected, the number of spans is automatically asigned as 2 and can be changed in function of the real number of spans of the bridge. For each span, the properties are needed to be defined as shown in Fig. 7

2. For boundary condition (BC), there are two options that can be selected: simply-supported




| | L (m) | EI (N.m2) | GJ (N.m2) | m (kg/m) | r (m) |
|---|---|---|---|---|---|
| 1 | 15 | 1.5e10 | 0.5e10 | 20000 | 0.25 |

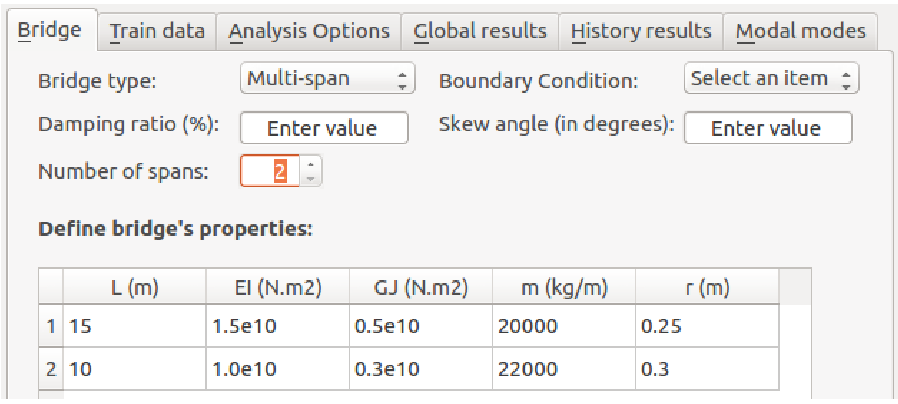
Figure 5: Define properties for single-span bridge




| | L (m) | EI (N.m2) | GJ (N.m2) | m (kg/m) | r (m) |
|---|---|---|---|---|---|
| 1 | 15 | 1.5e10 | 0.5e10 | 20000 | 0.25 |
| 2 | 10 | 1.0e10 | 0.3e10 | 22000 | 0.3 |
| 3 | 15 | 1.5e10 | 0.5e10 | 20000 | 0.25 |

(a) (b)

Figure 6: Define properties for portal frame bridge




| | L (m) | EI (N.m2) | GJ (N.m2) | m (kg/m) | r (m) |
|---|---|---|---|---|---|
| 1 | 15 | 1.5e10 | 0.5e10 | 20000 | 0.25 |
| 2 | 10 | 1.0e10 | 0.3e10 | 22000 | 0.3 |

Figure 7: Define properties for multi-span bridge

at the end and fixed at the end. To select BC, it is just only to click on the select item at the right side and a small window will appear as shown in Fig. 8 that contains all BC options.

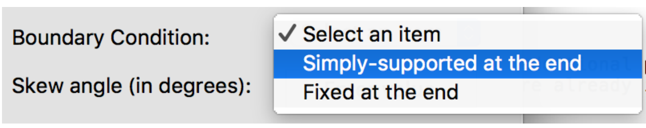



Figure 8: Selecting the BC options

3. The damping ratio of the bridge is introduced in percentage
4. The skewness of the bridge is introduced by the skew angle in degrees
5. Once all the bridge data is defined, it is necessary to submit those informations by clicking on the button "Save bridge". If any parameter of bridge has been not yet defined, an error message will be appeared automatically, indicating what type of error.

ATTENTION: In order to submit the job, the status of bridge in project summary should be "COMPLETED"

## 3.2 Definition of train data

In order to define the train data, we need to go to the "Train data" tab by clicking on this tab or using the shorcut "Alt+T". All options of this tab will be appeared as shown in Fig. 9.

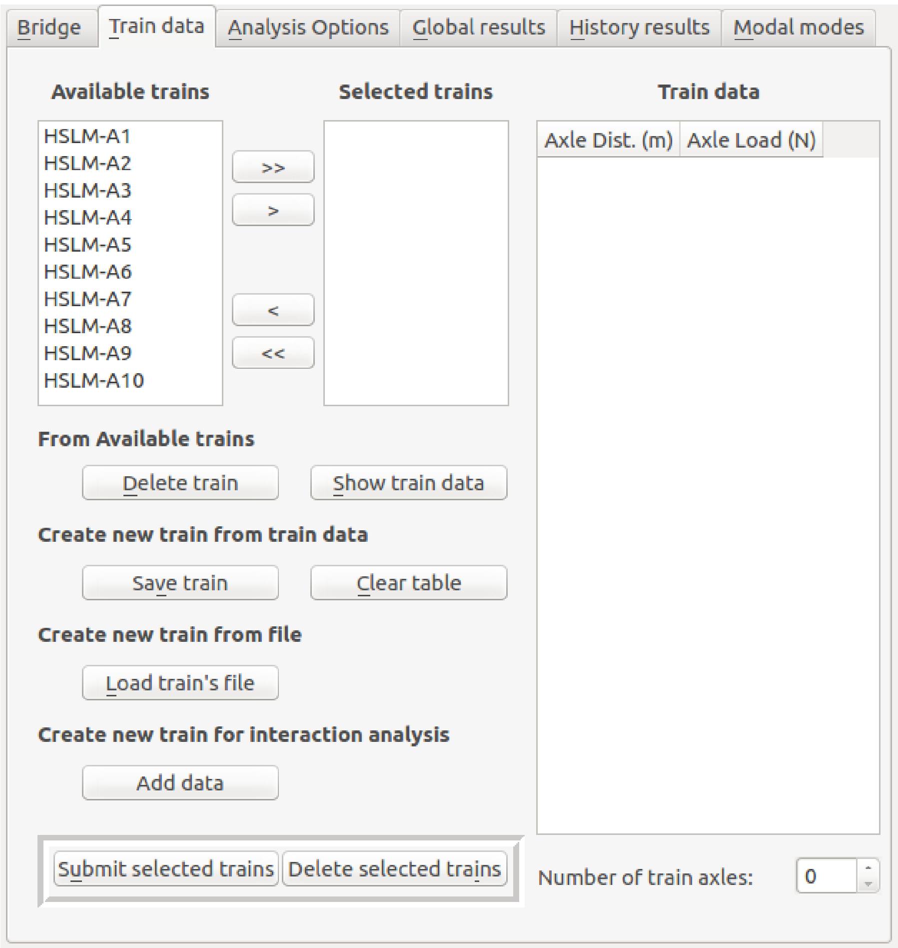
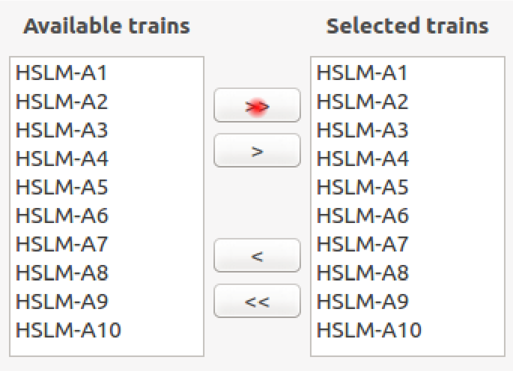
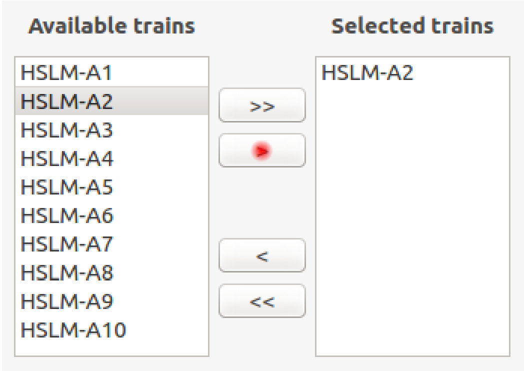



Figure 9: "Train data" tab in GUI of CALDINTAV

By default, there are ten trains listed in the **Available trains** that correspond to ten HSLM defined by *EN 1191-2:2003 Actions on Structures - Part 2: Traffic loads on bridges*. In the case that we only want to perform the analysis with one or more trains that are included in the list of **Available trains**, we just only click on the button ">>" to select all trains or ">" to select a train (see Fig. 10. The program allows the analysis with several trains at the same time. All selected trains will appeared in the list of **Selected Trains** that will be used for the analysis.




(a) Select all trains




(b) Select a train

Figure 10: Selecting trains for analysis

If you want to remove trains in the list of the **Selected trains**, just only click on the button "<<" to remove all selected trains or "<" to remove a selected train in the list.

The program also offers other options in this "Train data" tab:

- You can delete a train from the list of **Available trains** by selecting a train in the list and then using the button "Delete train".
- You can see the train's characteristics by selecting a train in the list of **Available trains** and then using the button "Show train data" that will be shown in the table of **Train data**. For example, Fig. 11 shows the train data of the HSLM-A2.

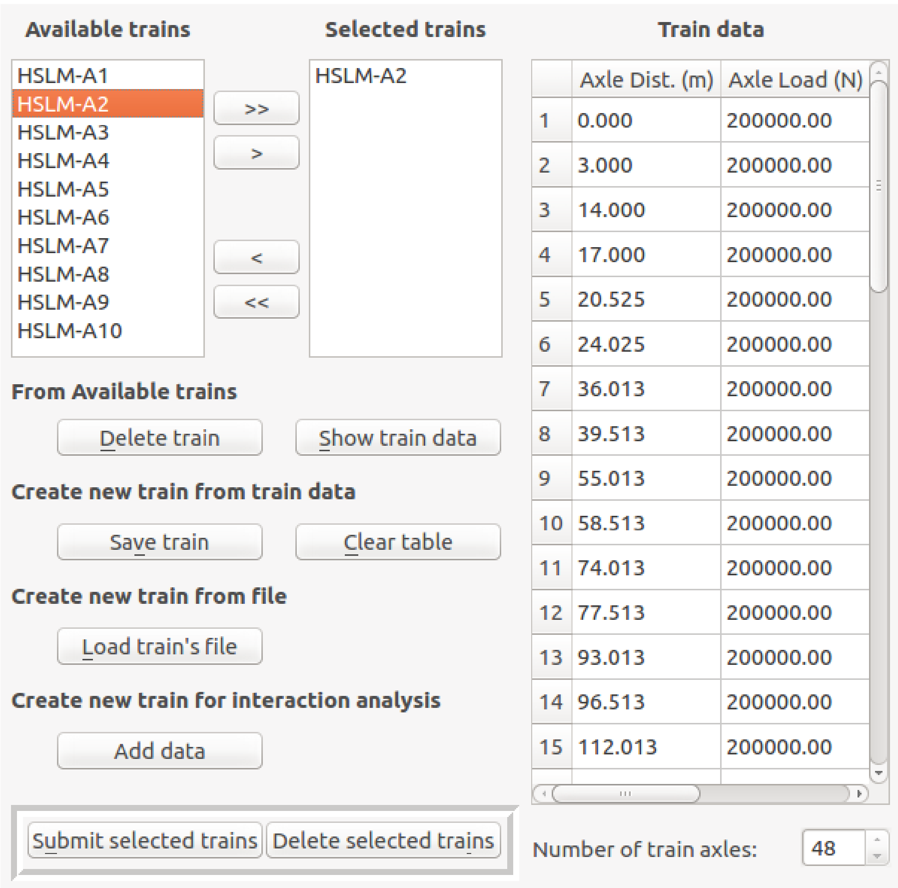
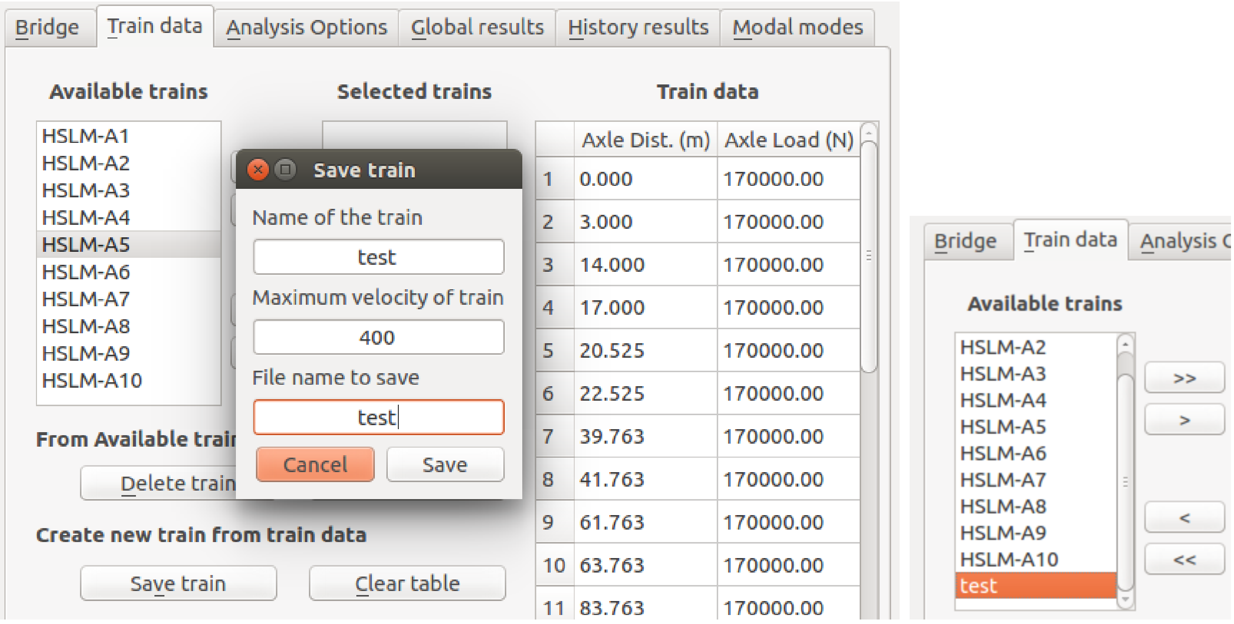



Figure 11: Showing the train data of HSLM-A2

- A new train can be created from the table of train data by using the the button "Save train". Once click on this button, a window will be shown, and you should enter: name of the train, maximum velocity for this train and the file name that you want to save (see Fig. 12(a)). The file that will be automatically saved in the "trains" folder. The new created train will be listed in the **Available trains** (see Fig. 12(b) and ready for selecting.




(a) (b)

Figure 12: Create a new train from the train data

- A new train can also be created by loading a file with extension *.dat or *.csv, using the button "Load trains's file". Once click on this button, a open file dialog will be appeared, and you can go to any folder that the train's data file is located. After selecting the train's file and clicking on "Open" button (see Fig. 13(a), a window will be shown as Fig. 13(b) in order to add the name of the train and its maximum velocity. The new created train will be also listed in the "**Available trains**" and ready for selecting.

- In the case that the dynamic analysis is performed using the vehicle-bridge interaction model, it is necessary to define the train properties that contain the data of the 1/4 bogie model as: axle distance, axle load, mass of wheel, mass of bogie, stiffness and damping of the primary suspension. The program offers the posibility to create this type of train data by clicking on the "Add data" button. A window will be appeared, and you need to fill the table with the train properties as shown in Fig. 14(a). You can fill the table manually, or paste the data from the clipboard of the exel file, or import from the file (*.dat or *.csv) by clicking on the "Import from the train's file" button and then selecting the file that you want to import (see Fig. 14(b)). Once all data is added, the new train will be listed in the "**Available trains**" is ready for selecting.

Once all desired trains are selected for the analysis, it is necessary to submit the selected trains by clicking on the button "Submit selected trains".

ATTENTION: In order to submit the job, the status of Trains in Project summary should be "COMPLETED". Furthermore, it is not possible select both the train for moving load and the train for interaction.

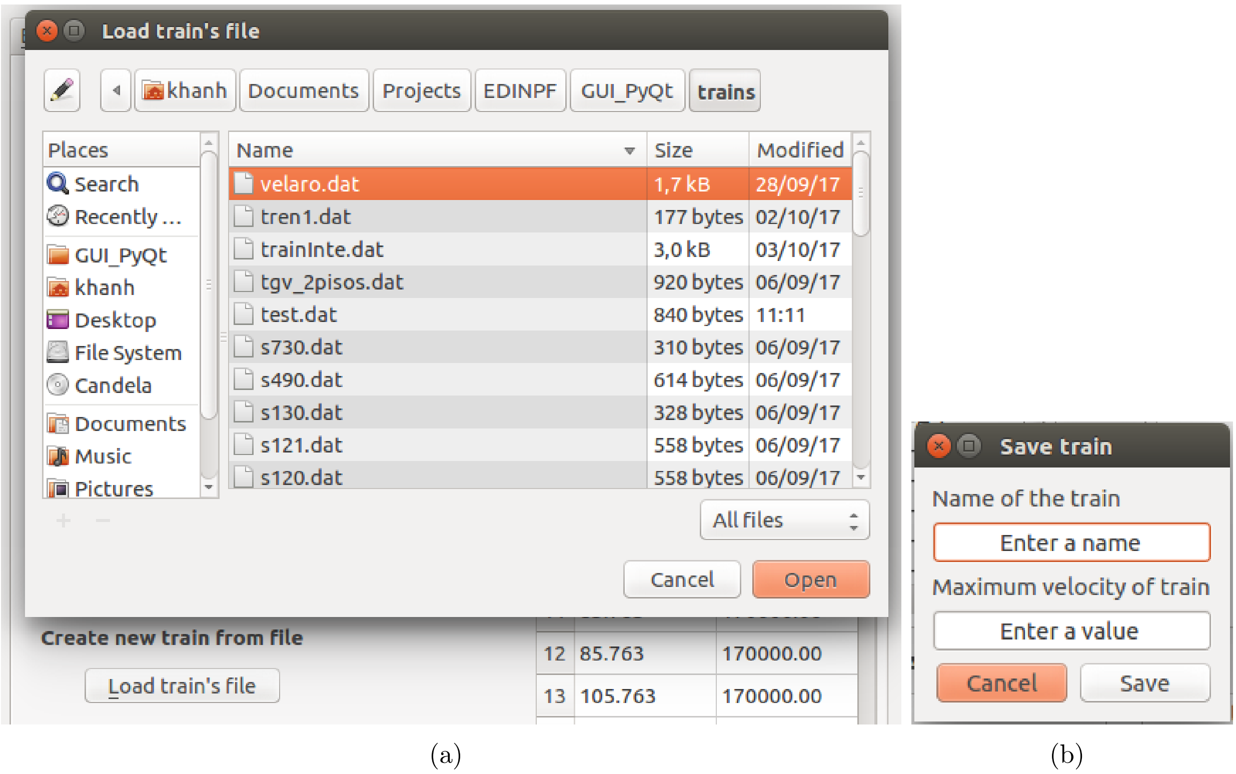



Figure 13: Create a new train from the train file

## 3.3 Definition of analysis options

The user can specify the type of analysis, train speed range, modal analysis options, advanded options in the "Analysis options" tab (see Fig. 15). In this version of CALDINTAV, there are four methods of dynamic calculation are supported: moving load method, DER method, RIL method and vehicle-bridge interaction model. By default, the moving load method is selected. The user can change to other option by clicking on the option that is desired to be used.

A range of train speed is introduced in the analysis by defining the minimum and maximum train speed and ist speed increment.

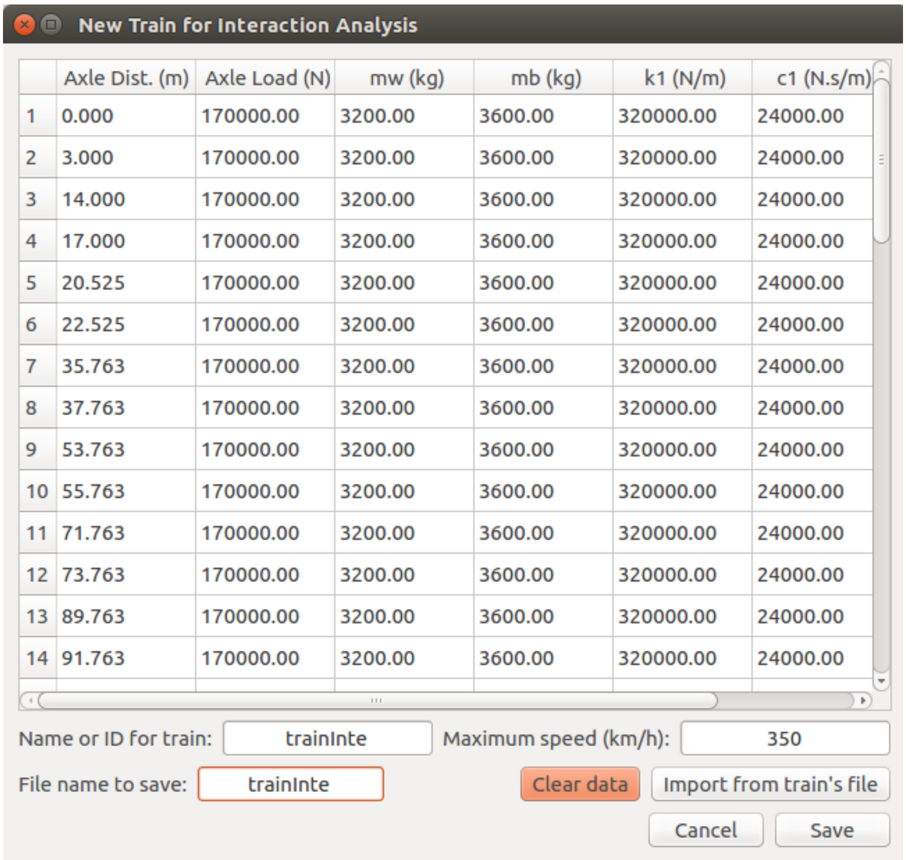
The user can modify the number of modes considered in the modal analysis by changing the number in "Number of modes". The time increment considered in the analysis also can be changed.

Furthermore, advanced options can be selected:

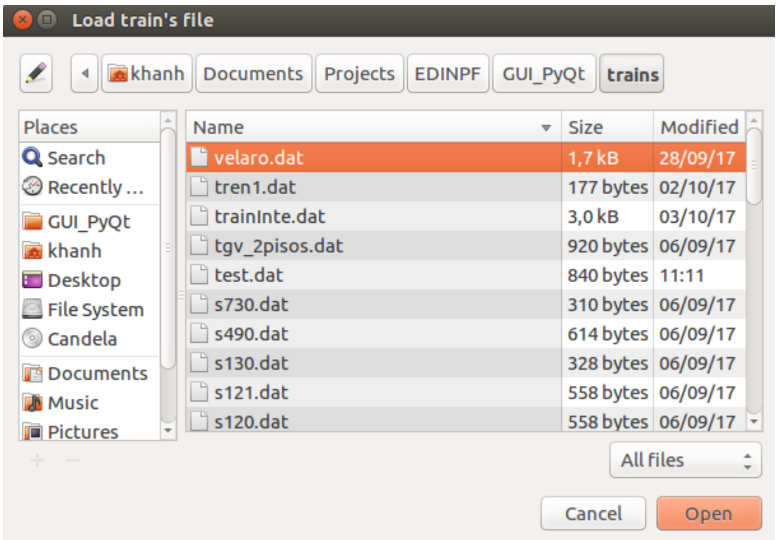
- Longitudinal distribution of axle loads either as point force or distributed by track following *EN 1191-2:2003 Actions on Structures - Part 2: Traffic loads on bridges*, section 6.3.6.1. This option is actived when you click on the "Load distribution" and then a sleeper distance should be defined. By default, the sleeper distance is proposed as 0.60 m.

- This program offer a posibility of changing the monitored point. By default, the monitored point is the mid-span of the bridge. This option is actived when you click on the option "Change default monitored point", and then the monitored point distance must be defined.

- The posibility of performing the calculation in parallel is also supported in this version of CALDINTAV. This option is actived when you click on the option "Paralllel computing" and specify the number of core that you want to use for the calculation. It is noted that, if the number of cores is larger than the cores of the computer, the program will take automatically the number of cores of the computer.




(a) New train for Interaction Analysis




(b) Import from file

Figure 14: Create a new train for the interaction analysis

Once all analysis options are defined, it is necessary to submit those options by clicking on the button "Save options".

ATTENTION: The status of Anal. Opt. in Project summary should be "COMPLETED". If it is not, try to save the options and see the error menssage

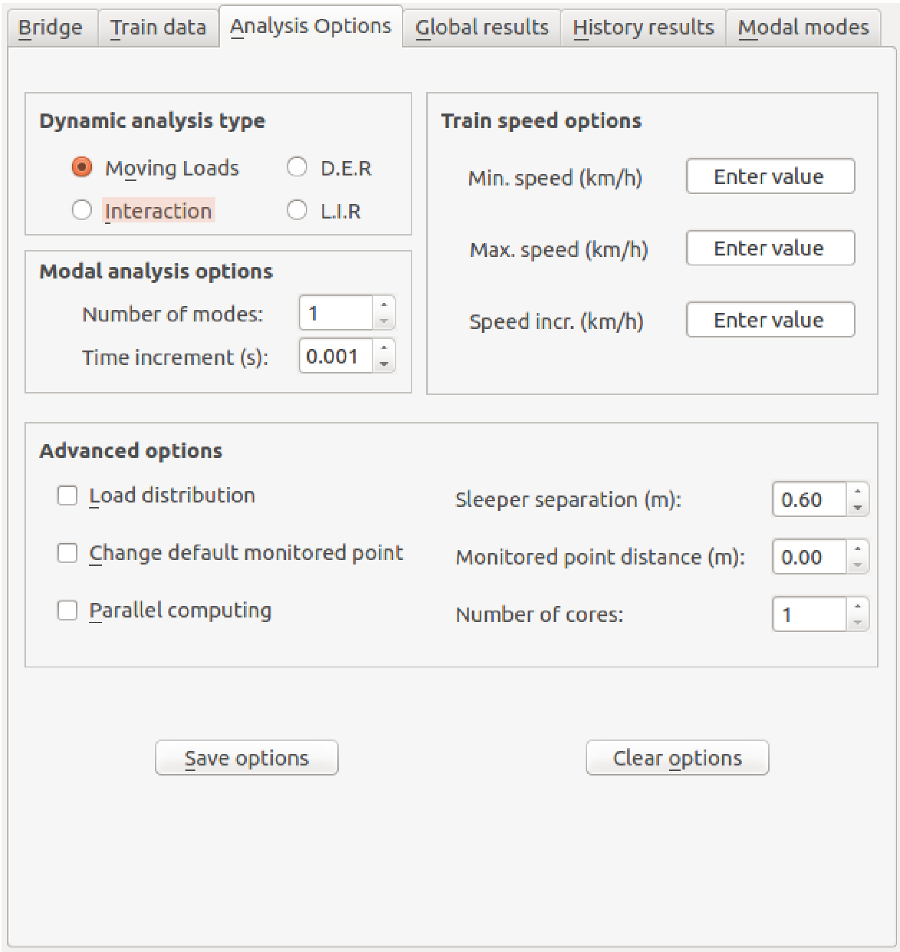



Figure 15: "Analysis options" tab in GUI of CALDINTAV v3.0

## 3.4 Results

Once the calculation is performed, CALDINTAV will generate two types of files that are stored in a folder "**CALDINTAV directory/project name/**". The first type of file save the time history of displacement, velocity and acceleration of the monitored point for each train and for each velocity and has the following format:

```
TrainName−anal_type−skew−span−damping−frequency−mass−num_modes−velo.dat
```

For example, the result file "`HSLM-A1-ml-skew0.0-L15.0-z2.0-f6.0hz-m20.0t-nm1-v300.dat`" corresponds to the result for the case that the HSLM-A1 train is considered. The moving load method is applied for the calculation. The bridge has skew angle of 0.0, span length of 15.0 m, damping of 2.0 %, natural frequency of 6.0 Hz, mass per unit length of 20.0 tons, number of modes considered is 1 and the train runs with speed of 300 km/h.

The other result file save the maximum displacement, velocity and acceleration at the monitores point for all range of train velocity. This file type has the following format:

```
TrainName−envelope−anal_type−skew−span−damp−freq−mass−num_modes−velo_range.da
```

For example, the result file "`HSLM-A1-envelope-ml-skew0.0-L15.0-z2.0-f6.0hz-m20.0t -nm1-v150-400.dat`" corresponds to the envelope result of the case that the HSLM-A1 train is considered. The moving load method is applied for the calculation. The bridge has skew angle of 0.0, span length of 15.0 m, damping of 2.0 %, natural frequency of 6.0 Hz, mass per unit length of 20.0 tons, number of modes considered is 1 and the train runs in speed range from 150 km/h to 400 km/h.

Furthermore, CALDINTAV v3.0 offers three tabs for visualizing the results of the calculation: Global resuts, History results and Modal modes. Detailed description of each tab is described in the following section.

### 3.4.1 Global results

In this tab, the user can plot the maximum acceleration and the dynamic amplification factor (DAF) at the monitored point in the bridge for the range of train velocity and for one or more trains that are selected previuosly. All selected trains for the calculation are listed in "**Selected trains**". In order to plot the result, you need to select a train and include it in the list of "**Plotted trains**" by clicking on the button "Include train". If you desire to eliminate one or more trains in the list of "**Plotted trains**", you can use the button "Remove train".

Once the plotted trains are selected, click on the button "Plot results" to visualize the results. Fig. 16 shows an example.

To facilitate the intepretation of the results, some buttons are provided. The button "Max. Acel. Limit" plots the limit of acceleration for different types of the track. Ballast track is selected by default. The other button "UIC Imp. Factor" plot the limit of DAF defined by the UIC-776. This option is only actived when the bridge is simply-supported.

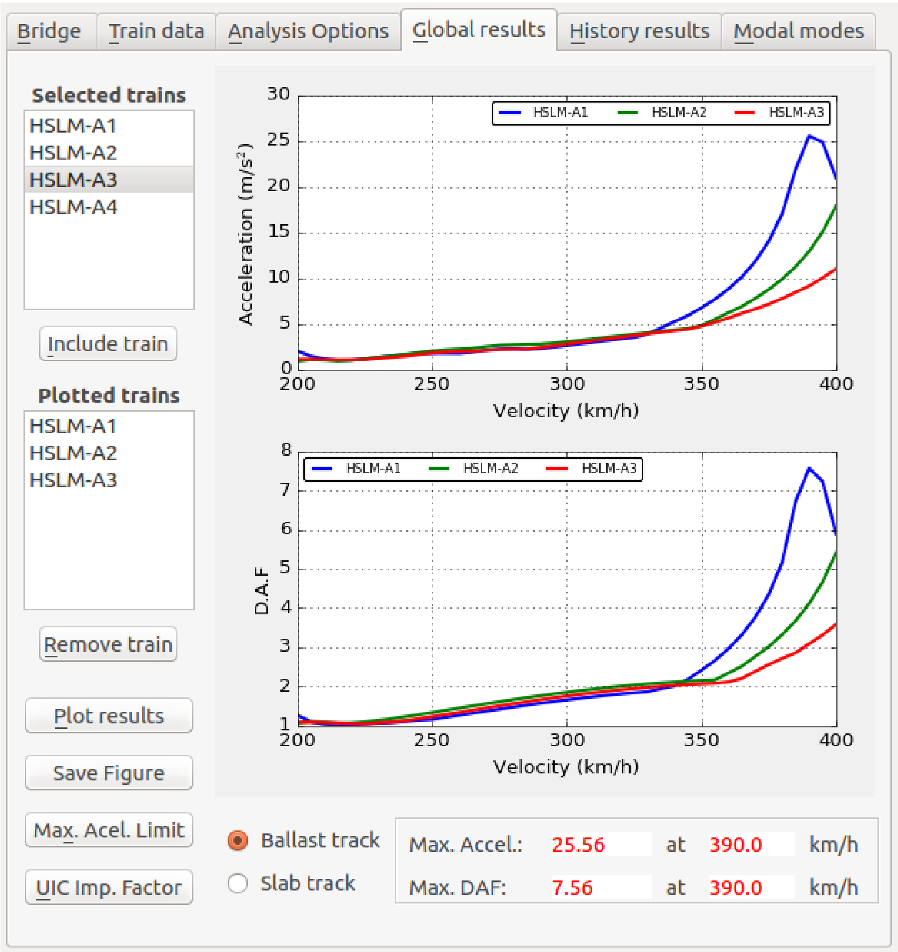
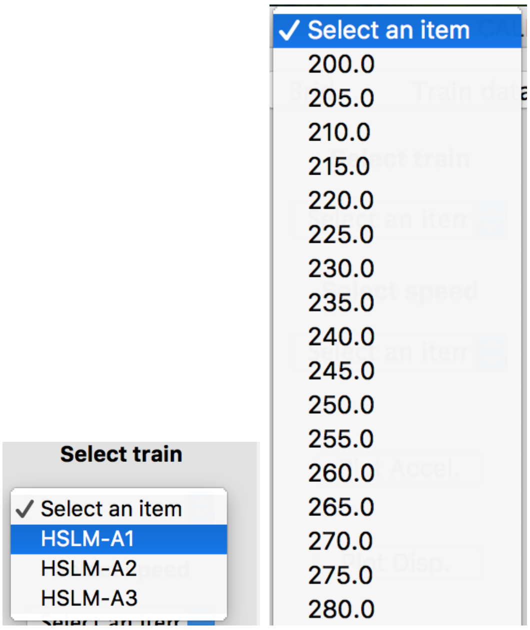



Figure 16: "Global results" tab

The plotted results can be saved in the png format by clicking on the button "Save Figure".

### 3.4.2 History results

In this tab, the time history of displacement or acceleration at the monitored point and its analysis in frequency content can be plotted. All selected trains in the calculation are listed in the combobox under "**Select train**". To select a train, it is just only to click on the select an item, all selected trains will be shown (see Fig. 17(a)). All train speeds are also listed in the combobox under "**Select speed**". To select a speed, just only click on the select item and select one of the train speeds as shown in Fig. 17(b).




(a) (b)

Figure 17: Selecting train and its speed for plotting

Once the train and its speed are selected, you can plot the time history of acceleration and its frequency content by clicking on the button "Plot Accel." or for the displacement by clicking on the button "Plot Disp.". Fig. 18 shows a plot of acceleration for the HSLM-A1 train at speed of 220 km/h.

### 3.4.3 Modal modes

In this tab, the user can plot the modes of vibration of the bridge that are considered in the calculation. The program offers to plot for both vertical and torsional mode shape if exists. Fig. 19 shows the first vertical mode of vibration of a simply-supported bridge.

# 4 Tutorials

## 4.1 Analysis of a simply-supported bridge under a comvoy of moving loads

## 4.2 Analysis of a multi-span bridge using the interaction model

## 4.3 Analysis of a portal frame bridge under diferent HSLM trains

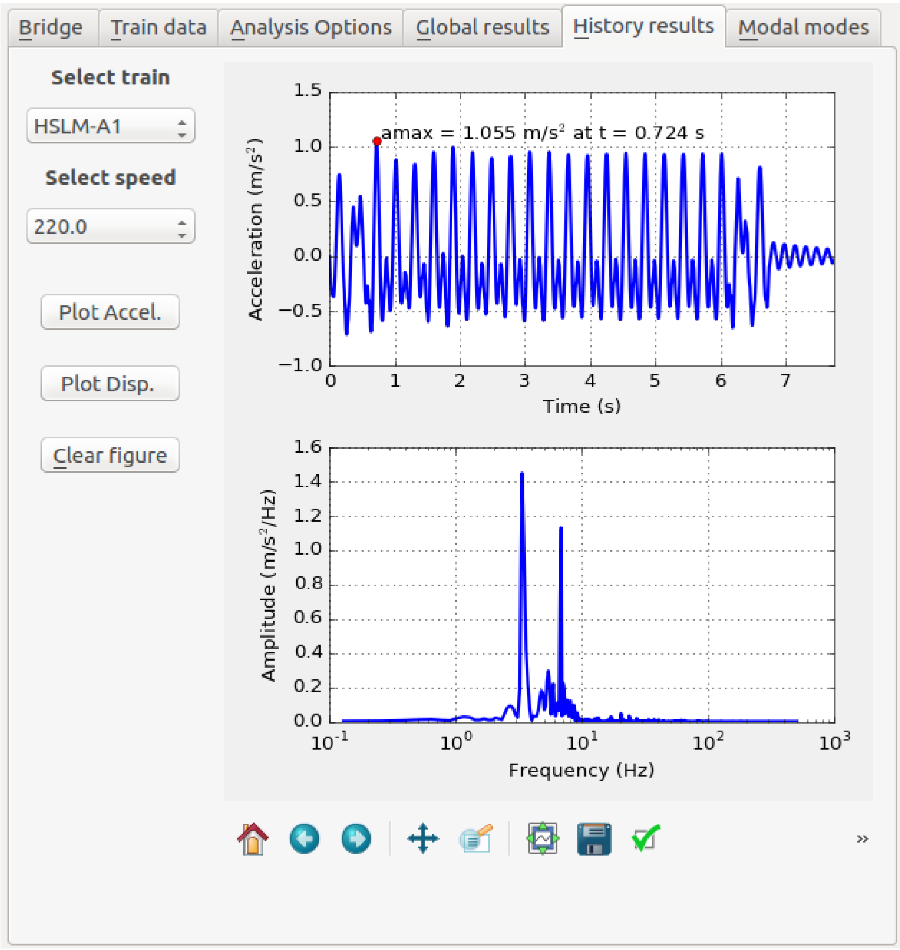



Figure 18: “History results” tab


Figure 19: “Modal modes” tab