Alizé2

User's Manual

Road design

Frost verification

May 2021

Alizé2®, Version 2.0.6

Documentation, Version 2.1, May 2021

Record of software versions: see in Appendix A2: Versions

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The following pictograms will be used to help guide the reader through this document:

Note, helpful piece of information

Sound idea, suggestion

Warning

Reference text

CONTENTS

1 Introduction

Alizé2® is a pavement structural design software based on the French design method and compliant with the design standard for new pavement structures (NF P98-086) [1]. Moreover, it relies on the stress and strain calculations in the context of Burmister's model [2]. The layout is composed of a superposition of semi-infinite layers in a plane lying on a mass of semi-infinite soil. The behavior of all materials is assumed to be linear elastic.

This software has been developed by the Université Gustave Eiffel (formerly LCPC and then Ifsttar), in collaboration with the STAC Technical Center for the aeronautics module.

Alizé-LCPC®, Alizé-Aeronautique® and Alizé2® are all registered trademarks.

1.1 Brief overview of the software

1.1.1 Origins

During the 1950's, French research in the field of transportation had sought to implement a method based on the calculation of stresses and load resistance in order to categorize and select certain pavement structures.

The necessary reconstruction of France's road network subsequent to the harsh 1962/63 winter, at that point the coldest of the century[1], accelerated the automation of road structure calculations. Thus began the development phase of the Alizé-LCPC® software, initially outsourced in 1963 to a software development firm.

As of 1964, the development process was being coordinated in-house at LCPC in Fortran language, with data entry on punch cards or tape and solely paper printouts. The implementation of Alizé on the mainframe Iris 80 computer made it possible to enter data via networked terminals, although the interface remained in a strictly text mode.

1.1.2 Alizé hits its stride

Beginning in 1976, the Public Works Ministry's program to undertake coordinated improvements to the nation's road network heightened the needs for such a design software, whose initial versions had focused on basic mechanics. The technical recommendations and guides of the period, bolstered by the subsequent standards adopted, laid the framework for the calculation methods, which entailed comparing the stresses and strains calculated by the software with the set of admissible values.

These evolutions were coupled with capital investments in powerful computers in order to run the requisite simulations.

During the 1970's, LCPC made the Alizé-LCPC® software and its installation by an in-house expert available to France's large construction companies operating internationally as well as to foreign civil engineering project professionals. As an option, this service included granting a software license and training staff in its proper use.

[1] https://fr.wikipedia.org/wiki/Hiver_1962-1963_en_Europe

The 1980's ushered in microcomputers and the increased computational power of PCs. The calculation engine was optimized, while remaining in Fortran, offering the potential for local use.

Over the course of the 1990's, the man-machine interface was reconfigured and developed in Visual Basic for a more user-friendly experience. The marketing of this first version of Alizé-LCPC® began in 2003 and included both graphic windows and personalized recordings of results.

1.1.3 Most recent developments

Gaining momentum from its commercial launch, Alizé-LCPC® pursued its development in order to not only respond to user requests and updates of standards, but also propose new modules that take advantage of the computers' enhanced computing power.

The latest version (1.5) of Alizé-LCPC®, developed in Visual Basic 6, was released in 2013 and was able to incorporate:

- the basic road Design module for dimensioning structures subjected to standard loading (single or twin axle);
- the freeze-thaw module (frost verification), which requires a thermal calculation compliant with the current standard;
- the aeronautical module, involving a wide range of calculations under various loading configurations. This module serves to cement the extensive collaboration between LCPC, later to become Ifsttar, and the STAC Technical Center;
- the special loads module used to carry out computations under various load configurations for specific applications like airport runway pavements or urban pavements (tramway lines);
- the back-calculation (or revere calculation) module, necessitating iterative calculations within an optimization framework.

These commercial modules were combined with an array of "research" functionalities developed for - and sometimes with - Ifsttar's myriad partners involved in transportation infrastructure design.

1.2 Overhaul of the software

In 2016, Ifsttar's management team decided to completely rewrite the software in response to various challenges. For one thing, maintaining the Alizé-LCPC® 1.5 application had become more complex due to the outdated VB6 language and its heightened vulnerabilities (cessation of Microsoft support since March 2008). Adding to momentum was the fact that this project provided the opportunity to revise the ergonomics of Version 1 through adaptation to a more modern user-friendly environment with enhanced features. Moreover, the update to design standard NF P98-086 [1] in May 2019 urging a software overhaul offered yet another incentive to embark on such a change.

A new team was thus assembled around pursuit of this mission.

In its fully comprehensive version, the Alizé2® project sets forth an objective of four main modules, namely:

- the *Road design* module;
- the *Aeronautical design* module;
- the *Back-calculations* module;
- the *Database management* module.

Let's note here that the first two modules incorporate a verification of the structure's satisfactory behavior in the presence of freeze-thaw cycles.

1.3 New features and strengths of Version 2

1.3.1 Choice of development tools and methods

Alizé2® has been developed in C++ language, within the Qt framework. The computation algorithms have been implemented in C++, whereas the interfaces are written in qml/Js.

The technological preferences introduced have added considerable flexibility compared to Visual Basic, a greater ease of maintenance, not to mention the many new functionalities yielding a vastly improved user interface.

Application maintenance is also enhanced by means of contemporary development methods coupled with a stringent software quality assurance plan.

1.3.2 Compatibility with Alizé-LCPC® Version 1.5

Alizé2® makes it possible, within a given project, to handle both structural files (.stu) and load files (.chg) generated by Alizé-LCPC® Version 1.5, as well as to continue with a design study initiated using the former version.

Conversely, the possibility still exists with Alizé2® to save a structure or load in the formats of Alizé-LCPC® Version 1.5.

1.3.3 Primary advances offered by Alizé2®

A range of functionalities have been added in order to upgrade and personalize the user's experience, with the following list highlighting the main ones:

- the software is compatible with the latest design standard NF P98-086 [1], as adopted in May 2019, integrating in particular new materials libraries, updated guides for "Average Aggressiveness Coefficient (AAC)", "Risks" and "Interface", plus an optimized computation mode for the frost verification;
- a structural coupling functionality has been added so that the frost verification can be assessed on the same structure as that implemented during the design modules;
- the main window is displayed as a succession of tabs representing the various stages of a structural study, with the multiplicity of pop-up windows now being limited to just those situations of necessity. The user thus gains improved visibility while navigating through the software;
- the notion project management is now fully integrated into the software;
- a definition of the road base course has been included in the structural composition;
- the admissible values calculation has since been integrated and tied to the structure itself. It also gets updated automatically upon each structural modification, e.g. each time the base course thickness is modified;
- the *Results* part now offers the option of directly modifying the structural thicknesses;
- the generation of new results-based curves have been made available;

- the customizable generation of a pdf formatted report is now possible as well. The user can add specifications on the study underway and choose the set of hypotheses and computation results to be included in the output.

These functionalities will be presented in detail in the chapter entitled "Description of the software".

1.4 Development priorities of the various modules

The project team is working on refining the next functionalities and subsequent modules according to the following priorities:

- "Aeronautical design" module (2021);
- "Back-calculations" module;
- "Expert" Mechanical part of the Road design module.

While awaiting the release of a number of Alizé2® modules, their functionalities remain available to users in Alizé-LCPC® Version 1.5.

The part on "Database management" will be developed and released later.

2 Description of the software

The software's home page window (Figure 2-1) shows four photos, each illustrating one of the application's main modules:

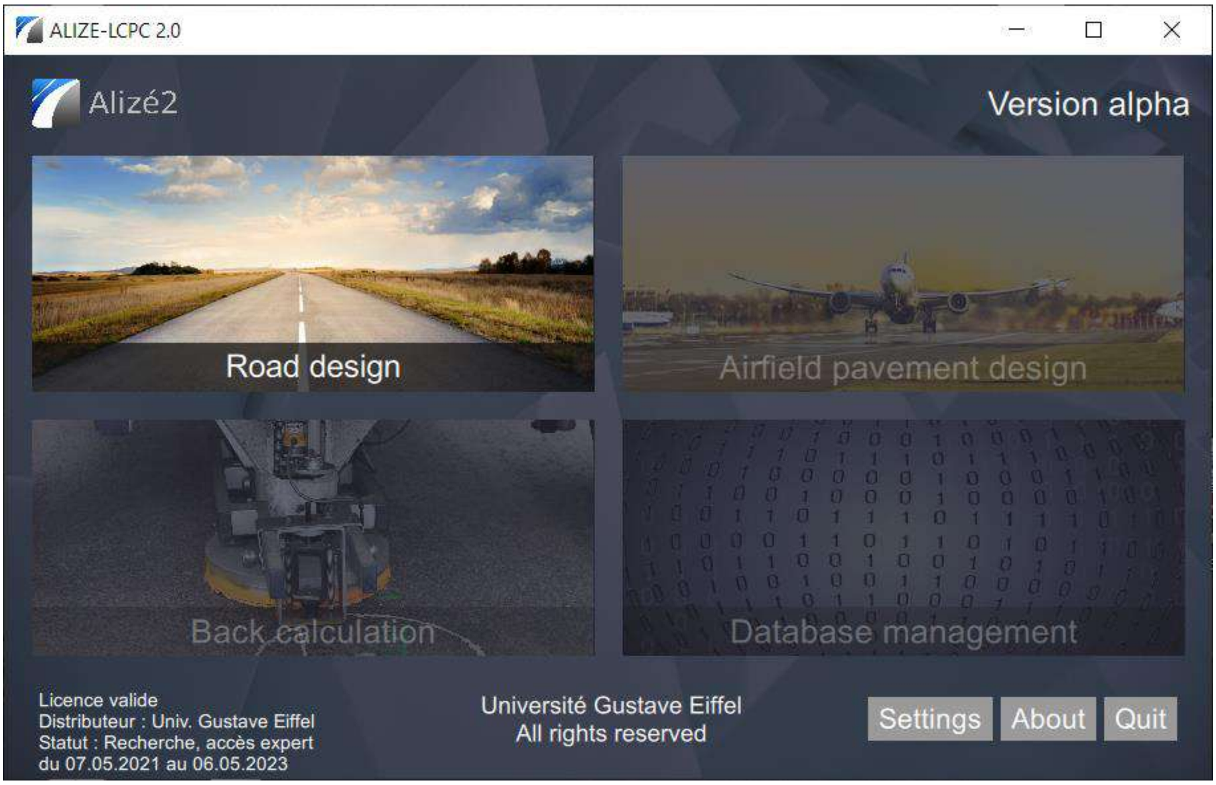


Figure 2-1: The application's home page display

The photos of the available modules have been brightened, while the shaded photos indicate those modules currently unavailable (either under development or license not yet activated). An available module opens by clicking the corresponding photo.

On the lower right, the *Quit* button closes the application, whereas the *About* button accesses information relative to the development credits.

2.1 Configuration of the general Alizé2® settings

By clicking the home page window's *Settings* button, Alizé2® proposes a screen (Figure 2-2) that serves to personalize:

- the interface language;
- the color guide;
- the display size of both textual content and interface controls.

As regards this last setting, it is possible to modulate the zoom value. The variation range depends on both the screen resolution and display setting in the operating system. The *High-resolution display* option allows increasing the maximum zoom value, as needed, for an optimal display.

In light of the extreme variety of hardware and software configurations, the user is asked to test and identify on his or her own the best display size for an optimal use of Alizé2®.

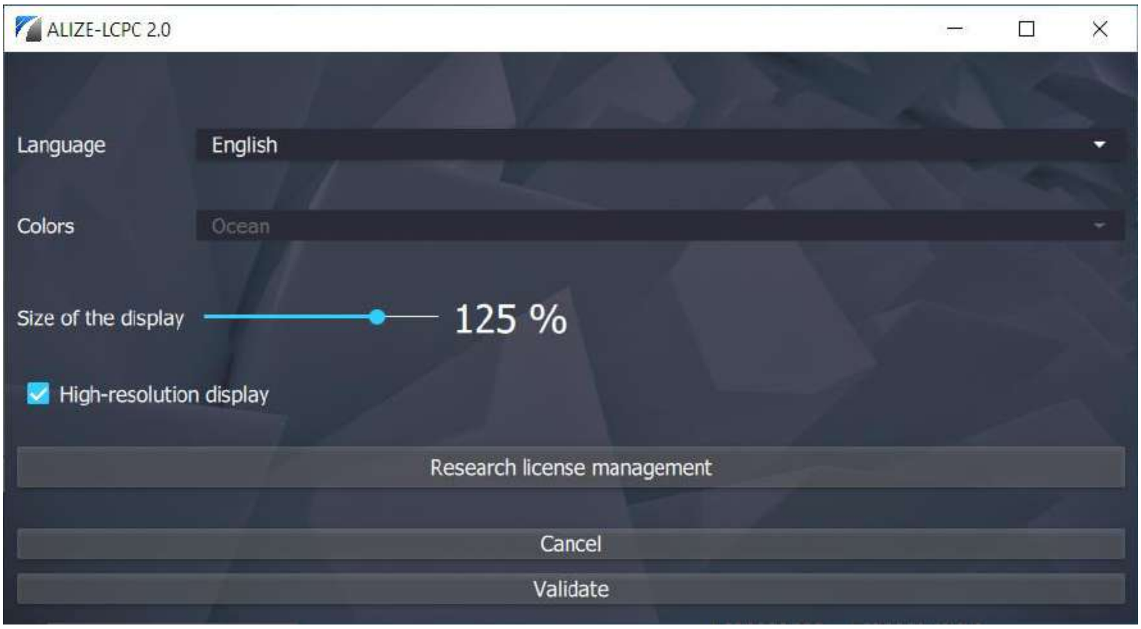


Figure 2-2: Settings configuration window

Moreover, in any of the Alizé2® screens:

- use of a shortcut combining the CTRL and + keys raises the zoom by successive 10% increments;
- use of a shortcut combining the CTRL and – keys lowers the zoom by successive 10% increments.

As a final point, the *Research license management* button enables entering the software key to unlock the research functionalities associated with this key. These licenses are provided by the Université Gustave Eiffel to its partners within the scope of designated research projects; their duration matches that of the partnership.

To exit the configuration without saving the modifications, the user will click on the *Cancel* button or else the *Validate* button.

2.2 Ergonomics and browsing

Use of the application relies on a simple browsing principle: by means of successive clicks on the tabs, the window contents change to offer the user the set of desired functionalities.

As such, to adjust the project settings of a Road design project, for example, the user will typically carry out the following steps in succession:

- on the home page window, click the Road design module button;
- click the *Standard* button;
- click the button to either create or open a project;
- once the structure has been configured in the initial screen, click the *Load* tab to specify the characteristics of the applied load (Figure 2-3);
- click the *Traffic* tab and enter the corresponding data;
- click the *Admissible values* tab and enter the corresponding data;
- click the *Results* tab.

The general appearance of a given window, as illustrated in Figure 2-3, is composed of:

- a contextual menu at the upper left (see red frame no. 1), as represented by three horizontal lines, whose contents are of a general nature and adapted to the current module;
- a *Home* button at the upper right (red frame no. 2) allows returning to the application's starting window;
- one or more "panels" (red frame no. 3). These may either be hidden, in order to free up space for the main set of information, or displayed depending on whether or not the user is seeking specific additional information. A panel may be located on any side of the screen (upper, right, lower, left), but more often tends to be on the right-hand side. Also note that two panels may be juxtaposed.

  A panel is delimited by a button offering the user two options, namely:

  - the first consisting of clicking above with the effect of hiding / displaying the panel;
  - the second consisting of positioning the mouse on the edge of this bar in order to transform the cursor into a double arrow, followed by a click & drag towards the left or right with the effect of modifying the panel width;

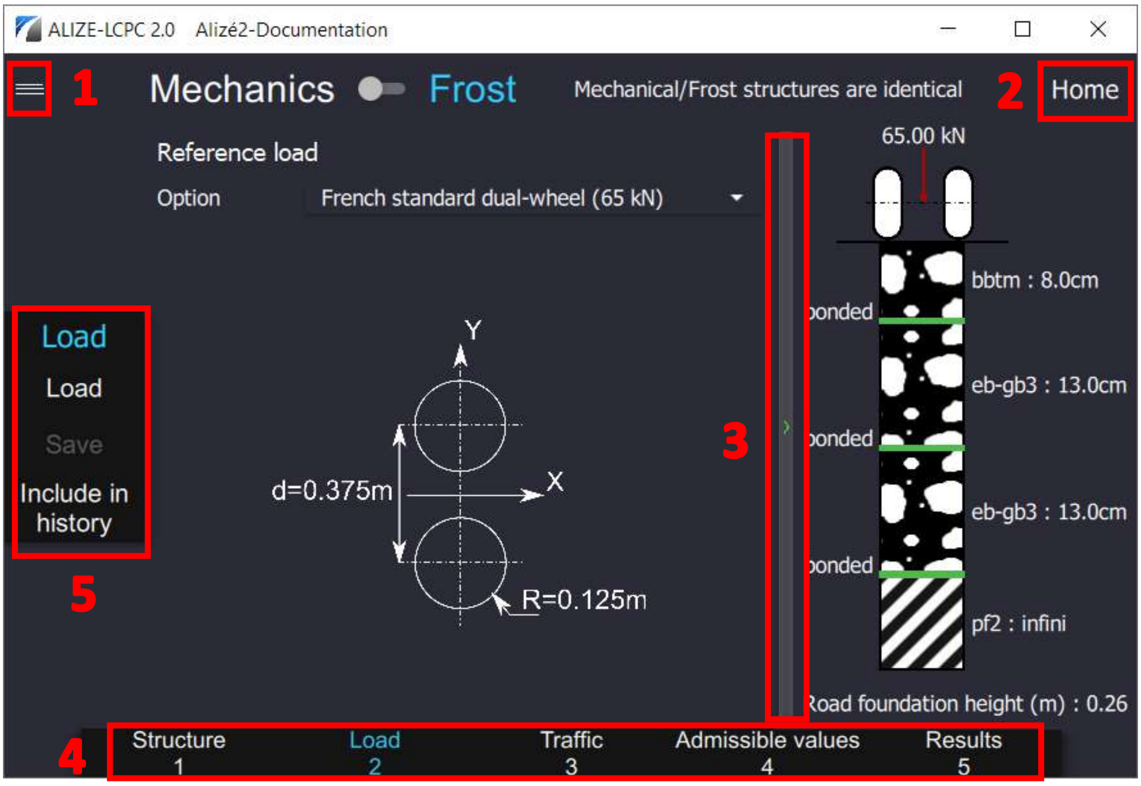


Figure 2-3: General browsing elements – example of the Load tab for a standard Road design

- a navigation bar at the bottom (red frame no. 4), serving to advance step by step;
- a vertical menu, directly accessible on the left (red frame no. 5), which is adapted to the current step.

The control elements presented above are only displayed if needed to use the current window.

Inputs of numerical values in Alizé2®must be done using a dot « . » as decimal separator (and not a comma).

2.3 Project management

Managing a project entails the stages of: creation, description, save, reopen, close, and deletion.

2.3.1 Creating a new project

Once positioned in the desired module, the user must click the *New project* button (Figure 2-4):

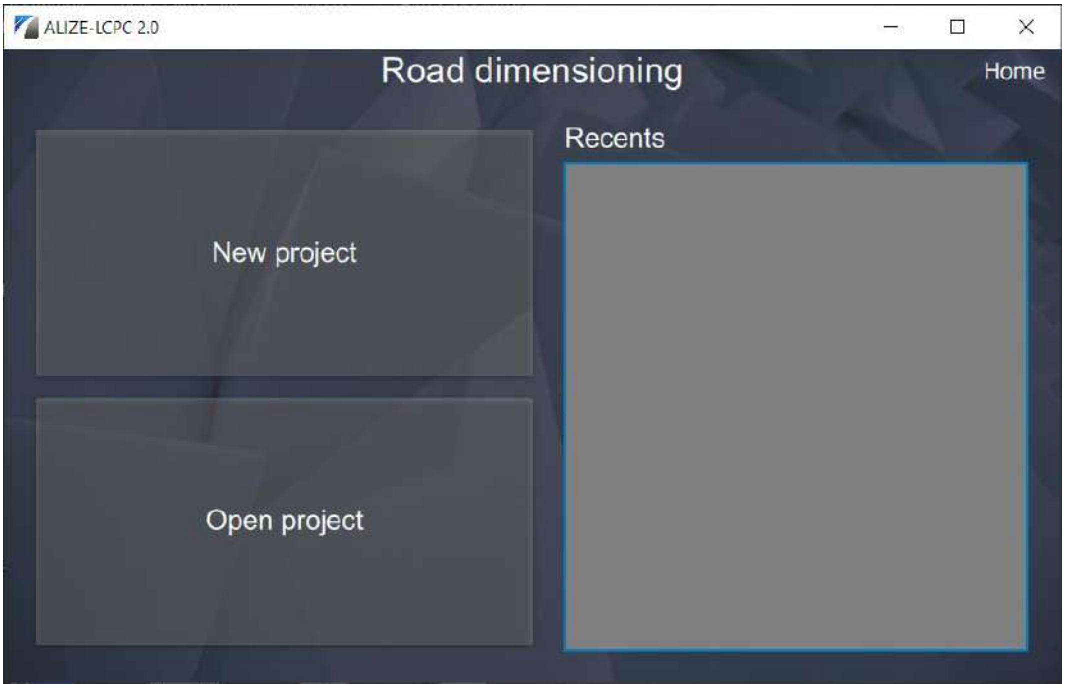


Figure 2-4: New project opening and creation window

The following window (Figure 2-5) makes it possible to input various fields related to the project and subsequently used to generate the mechanical report (see Section 3.2.5 Results Results):

The warning allows the user to alert the report recipient about one or more key points of the study.

The directory is that of the project backup, on which the user naturally holds overwrite access rights.

Clicking the *Next* button yields access to the actual project.

To enable saving a project onto a company's network, note that it is best to avoid using a network drive of the type Z:\.... Syntax "*name_server*\...".

Figure 2-5: New project definition window

2.3.2 Saving a project

After modification, the project may be saved via the menu shown on the upper left-hand side, as depicted by 3 horizontal lines (Figure 2-3).

A list of options opens. It is now possible (Figure 2-6) to save the project:

- in its current location, by clicking *Save*;
- in another location, by clicking *Save as*, and then selecting the new location.

Figure 2-6: Menu options available over the course of the project duration

2.3.3 Opening an existing project

To open a previously created project, several possibilities are available to the user, namely:

- upon launching Alizé2®, click the *Open project* button (Figure 2-4), then select the project in the dropdown list of files;
- a recently created project can be opened more quickly by making a single-click selection from the list shown in the right-hand block of the same window (Figure 2-4);

- while running Alizé2®, it is also possible to make use of the *Load* menu from the module currently being used (Figure 2-6).

2.3.4 Closing a project

Once a project has successfully been saved, the user can close it:

- either by clicking the *Home page* button - a warning message then appears (Figure 2-7):

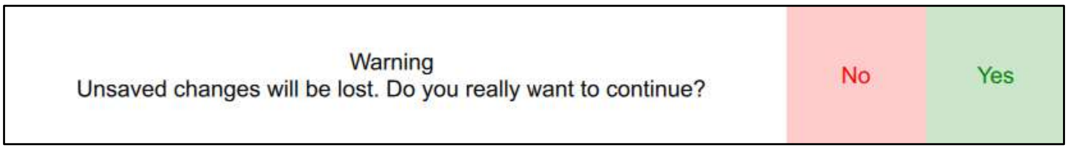


Figure 2-7: Warning message prior to closing the project

- or by simply closing the Alizé2® window.

2.3.5 Deleting a project

A project is deleted outside of the software environment, directly from the file explorer / manager application, at the location where the project has been saved.

3 Road design module

The Road design module contains three sub-modules (Figure 3-1), i.e.:

- a *Standard* sub-module;
- an *Admissible values calculation* sub-module;
- an *Expert* sub-module.

Figure 3-1: The Road design module and its three sub-modules

The *Standard* sub-module enables the user to perform a conventional Road design in compliance with the current standard by following the various steps of the Mechanical part, prior to ensuring its compatibility with harsh or exceptional winters in its Frost verification component.

The *Admissible values calculation* sub-module is dedicated to calculating the admissible stresses and strains for a given layer. In this manner, the user can define a traffic and a material before obtaining the calculation output. A reverse calculation of either traffic or risk is also possible.

The *Expert* sub-module offers the user advanced calculation functionalities, such as the calculation of structural variants or the design of structures subjected to special loads (e.g. oversized vehicles, construction equipment, overhead cranes, container vehicles).

3.1 General remarks

3.1.1 Context-driven menu

Throughout the various steps of the design stage, the contextual menu represented by three horizontal lines (in the upper left) serves to upload and existing project and save the current project (Figure 2-6).

It also provides access to two guides published in 2019:

- the interface guide;
- the guide for pavements featuring unique cross-sections.

These guides are thus accessible from all the tabs via this menu. Their use is presented in Section 3.1.4 Guides.

3.1.2 Diagram of the structure

On the right part of the screen, a retractable panel displays a diagram of the pavement structure currently defined, along with its various layers, as well as the load being applied to it (

Figure 3-2).

The layers are separated by interfaces colored according to their status: bonded (green), semi-bonded (green blue) or sliding (blue).

Each layer is illustrated by its name and thickness. A graph depicting the type of material is also associated with it.

Lastly, the base course height is indicated below the diagram and corresponds to the automatically calculated sum of the thicknesses of the individual layers defined as constituting the structure's base course.

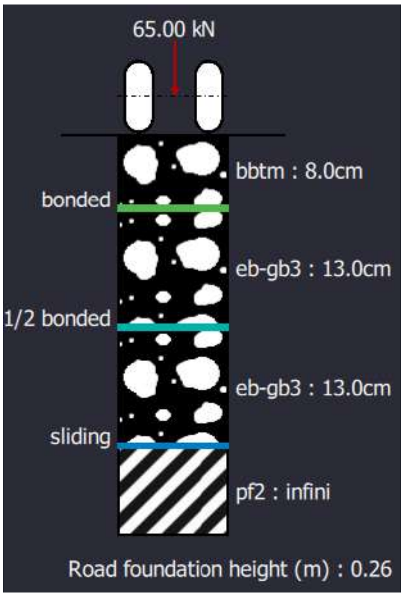


Figure 3-2: Diagram of the studied structure and its loading profile

3.1.3 Libraries of structures and materials

➢ The structures library

This library serves to select a predefined structure, by choosing in succession (Figure 3-3):

- in the left-hand column:
  - the type of road: structural network link (VRS) or non-structural link (VRNS);
  - the load-bearing class;
  - the pavement life cycle phase in the case of a hybrid structure;
  - the traffic class;
- then, in the middle column the sheet corresponding to the type of desired structure.

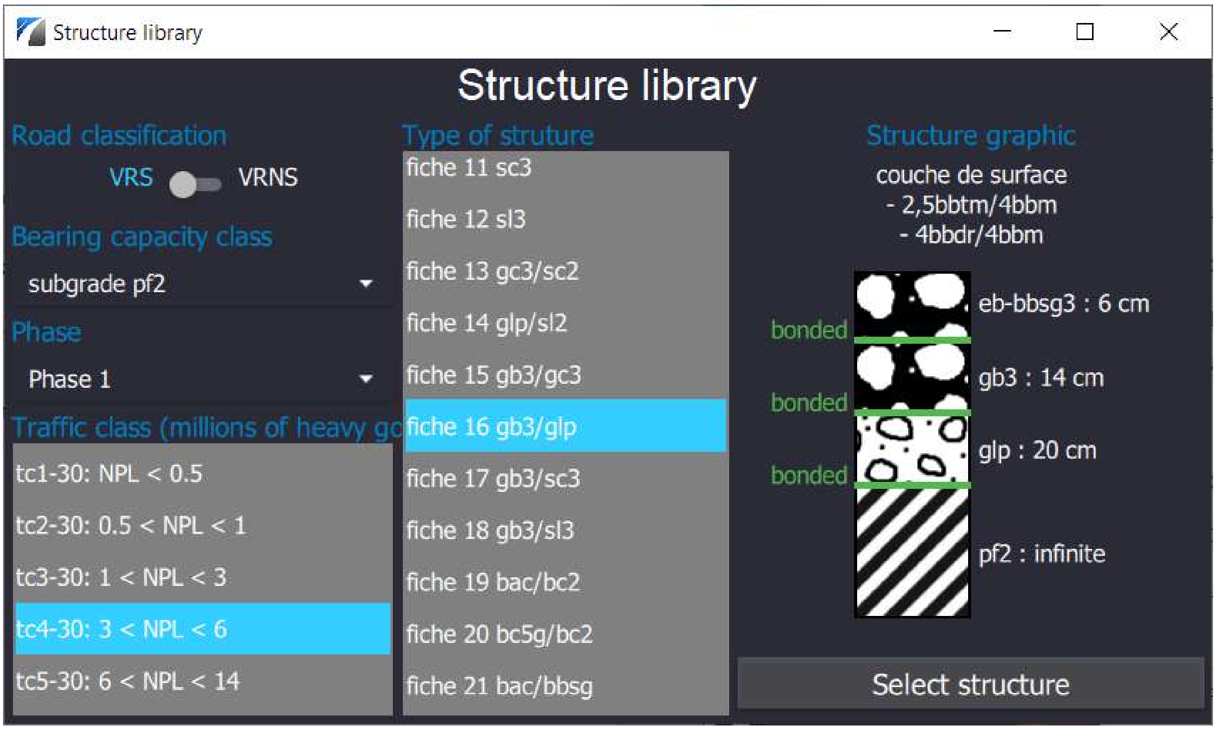


Figure 3-3: Selection of a structure in the library

If the structure is available in the right-hand column, then the corresponding diagram is displayed. By clicking the *Select the structure* button, the window automatically closes and the selected structure gets applied in the main Alizé2® window.

This library is not based on the materials library of the latest 2019 Standard NF P98-086 [1].

- The materials library

This library offers a decision-making aid for the materials of the structural layers by means of providing the values of various mechanical parameters.

For this purpose, the user makes use of three libraries (Figure 3-4, upper left red frame):

- the 1998 catalogue (first library proposed in ALIZÉ-LCPC, supplied within the scope of the pavement design guide [3])
- the library generated from the 2011 Standard NF P98-086;
- the library generated from the 2019 Standard NF P98-086 [1].

From one library to the next, a material can change its name and/or mechanical properties.

Use of the materials library generated from the most recent standard in effect [1] is recommended.

After having selected one of these libraries, the user is able to search for a material by browsing the various families available with the help of the tabs bar (bottom red frame).

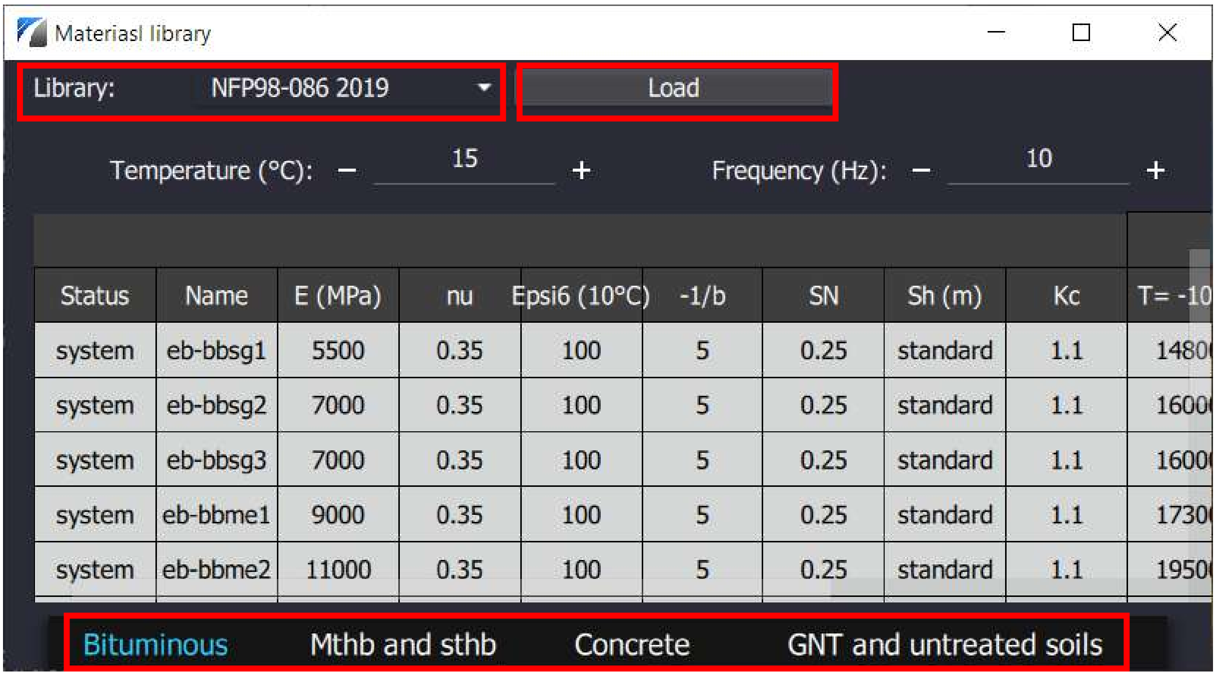


Figure 3-4: Characteristics of materials in the library

Moreover, the *Load* option (upper right red frame) allows importing one or more "user" libraries, by means of a file requiring a well-defined syntax whose description is given in Appendix A1.

All rows selected in the table appear in blue (Figure 3-5):

Figure 3-5: Selection of a material and visualization of its detailed heading

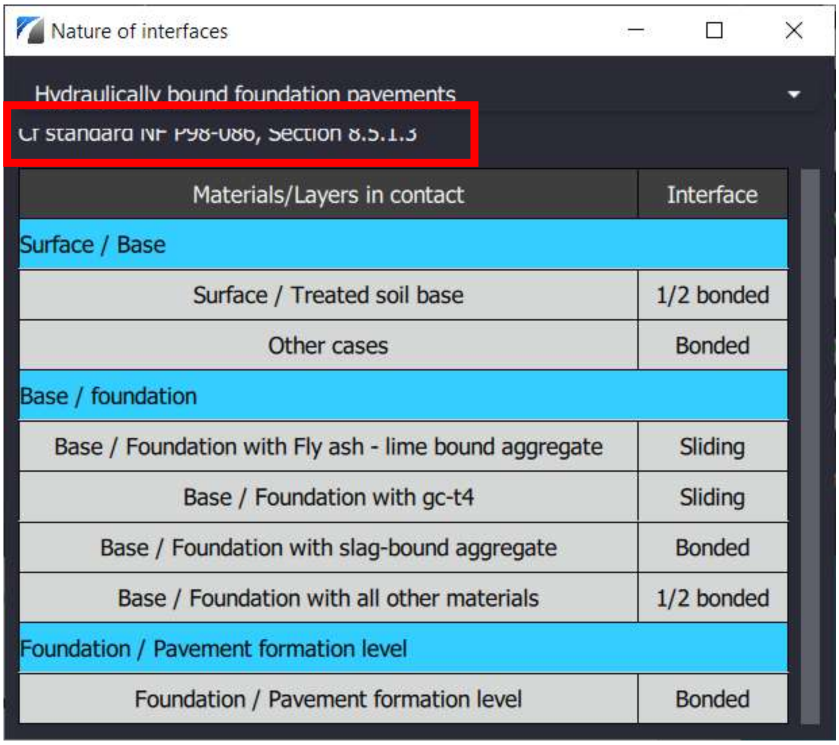
The detailed materials heading may be observed in the information bubbles appearing when hovering the mouse above each entry in the *Name* column (Figure 3-5).

For bituminous materials, it is possible to vary the temperatures and frequencies and then observe the ensuing consequences in the modulus of elasticity *E (MPa)* table. In the right part of the table, the value of *E* is indicated for staggered temperature values and a constant frequency of 10 Hz.

3.1.4 Guides

➢ The interface guide

This guide informs on the various possible **interface characteristics** (Figure 3-6) by type of pavement (flexible, hybrid structures, concrete, etc.).



Materials/Layers in contact	Interface
Surface / Base	
Surface / Treated soil base	1/2 bonded
Other cases	Bonded
Base / foundation	
Base / Foundation with Fly ash - lime bound aggregate	Sliding
Base / Foundation with gc-t4	Sliding
Base / Foundation with slag-bound aggregate	Bonded
Base / Foundation with all other materials	1/2 bonded
Foundation / Pavement formation level	
Foundation / Pavement formation level	Bonded

Figure 3-6: Characteristics of interfaces depending on the pavement type

For each type of pavement:

- a table indicates the nature of the interfaces between the various layers as a function of the component materials;
- Alizé2® indicates the paragraph of Standard NF P98-086 [1] the user can consult for further details (Figure 3-6, red frame).

➢ The guide for pavements featuring a unique cross-section

This guide provides information on various parameters (Annual Average Daily Traffic, AAC, Risk - Figure 3-7) for the special cases of the following pavements:

- highway on/off ramps;
- vehicle service areas - rest / parking areas;
- emergency shoulder lanes;
- traffic circles.

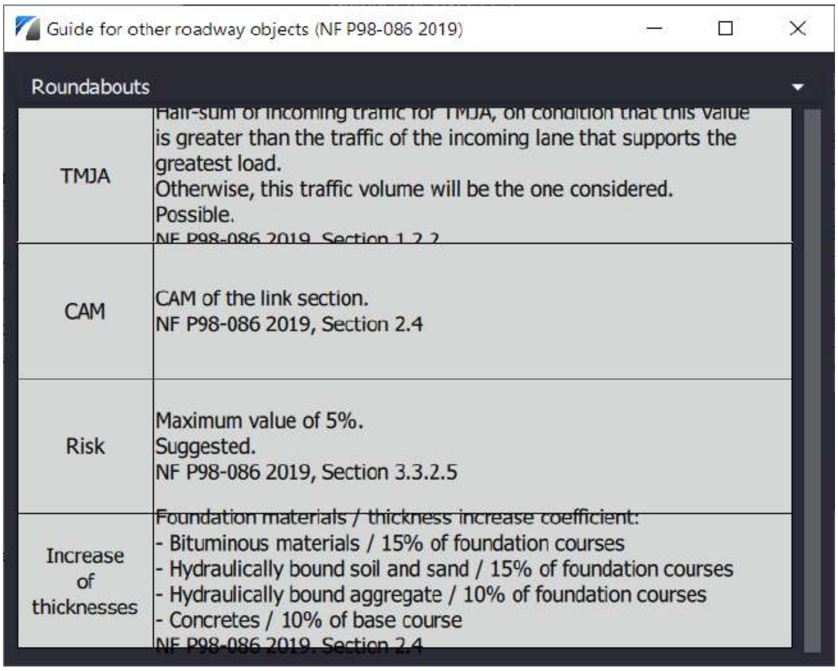


Figure 3-7: Guide for pavements featuring unique cross-sections – Example of traffic circles

For each situation, this guide indicates the reference of the cross-section targeted in Standard NF P98-086 2019 [1].

➢ The Average Aggressiveness Coefficient (AAC) and Risk guides

The AAC and Risk guides, which are made available when calculating admissible values, serve respectively to determine the average aggressiveness coefficient (AAC) and the risk value. For this purpose, the user selects the various options corresponding to the ongoing pavement design (Figure 3-8 and Figure 3-9):

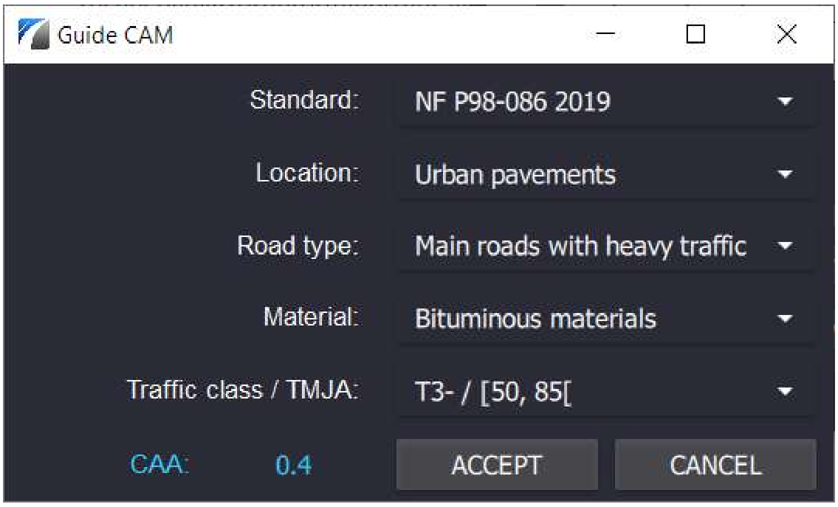


Figure 3-8: Determination of the AAC coefficient

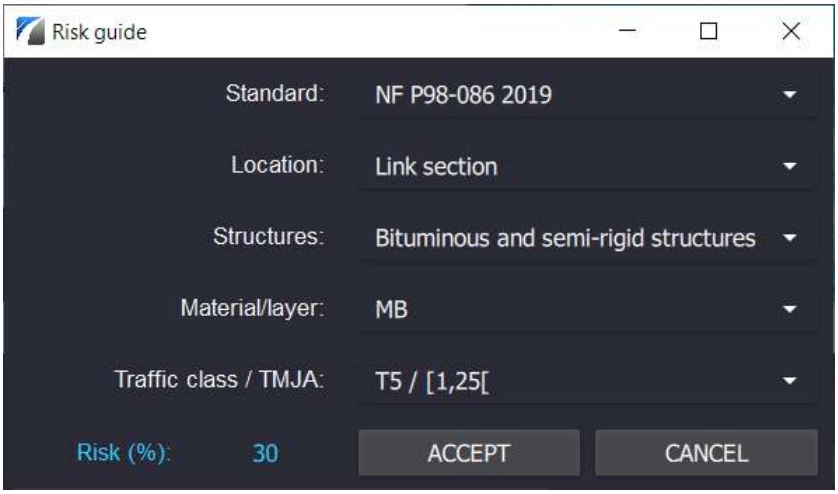


Figure 3-9: Determination of the risk

The resulting value, displayed in blue, is automatically updated. Upon entering input into all fields, the user can then click the *Accept* button to relay the value into the corresponding field.

For the AAC just like for the risk, it is critical to browse the fields from top to bottom. Each option proposed in fact depends on the user's previous choices.

3.1.5 Inclusion in the log

It is possible to save the selections made and results obtained during the design process in a text file. For this step, the *Include in the log* button is most often present in the vertical menu to the left of the Alizé2® window.

This file makes it possible to trace the activity, in order to compare several solutions, evaluate the variants, etc.
The result can be easily utilized to retrieve data in a spreadsheet, for example.

- Principle

The file, unique and independent of the tab being consulted, is created upon the initial *Include in the log* request. Each *Include in the log* click triggers the recording of a sequence of data associated with the current tab, subsequent to the previous sequence.

Upon closing Alizé2®, the file retains the information recorded and may be completed during subsequent sessions.

Each click of the *Include in the log* button records the information from the current tab in the file, whether or not other user actions have taken place in the software since the previous click.

➢ Location and format

This file is named *log.log* and can be read with various text editors (e.g. Notepad). It is recorded:

- in the same folder as the project (if the project has already been defined);
- otherwise in the location of the user's documents:

C:\Users\<User's Windows session name>\Documents

The file is never deleted, emptied of its contents or automatically moved by Alizé2®; however, the user is eligible to carry out the following actions.

➢ File structure

Each sequence possesses a defined structure, with:

- a title: Alizé 2;
- a subtitle: a name corresponding to the current tab (Structure, Load, Road traffic, Admissible values, Calculation result);
- a sequence time stamp: mm/dd/yyyy at hh:mm:ss;
- a series of *title / value* parameters whose number and format vary depending on the associated tab (all of the tab's useful data are recorded).

```
historique.log - Bloc-notes
Fichier  Edition  Format  Affichage  Aide
Alize 2
Structure

07/02/2021 à 10:56:19

Nombre de couches :     4
épaisseur       matériau        module  nu      type mat        bibliothèque mat
0.080   eb-bbsg3        7000    0.350   bitum   NFP98-086 2019  3       2       15.0
0.130   eb-gb3  9000    0.350   bitum   NFP98-086 2019  3       11      15.0    10.0
0.130   eb-gb3  9000    0.350   bitum   NFP98-086 2019  3       11      15.0    10.0
infini  pf2     50      0.350   plateForme      NFP98-086 2019  3       6       15.0
Nombre de variantes :   0
Code de variante (0: pas de variante, 1: épaisseur, 2: module E) :      0
1
```

Figure 3-10: Example of the log.log file

The successive sequences inserted each time the *Include in the log* button is clicked are not separated by any line spacing.

3.1.6 Frost verification

A separate module is dedicated to the frost verification of a road pavement structure.

Refer to Chapter 4 Frost verification.

3.2 Standard mechanical design

Once the project has been opened or newly created (see Section 0 Inputs of numerical values in Alizé2®must be done using a dot « . » as decimal separator (and not a comma).

Project management), the user will be able to undertake the mechanical design phase by executing the various required steps as exposed by the tabs bar at the bottom of the screen (Figure 3-11):

Figure 3-11: Tabs bar of the Standard sub-module –Mechanical part

3.2.1 Structure tab

The first tab serves to define the structure to be designed (Figure 3-12).

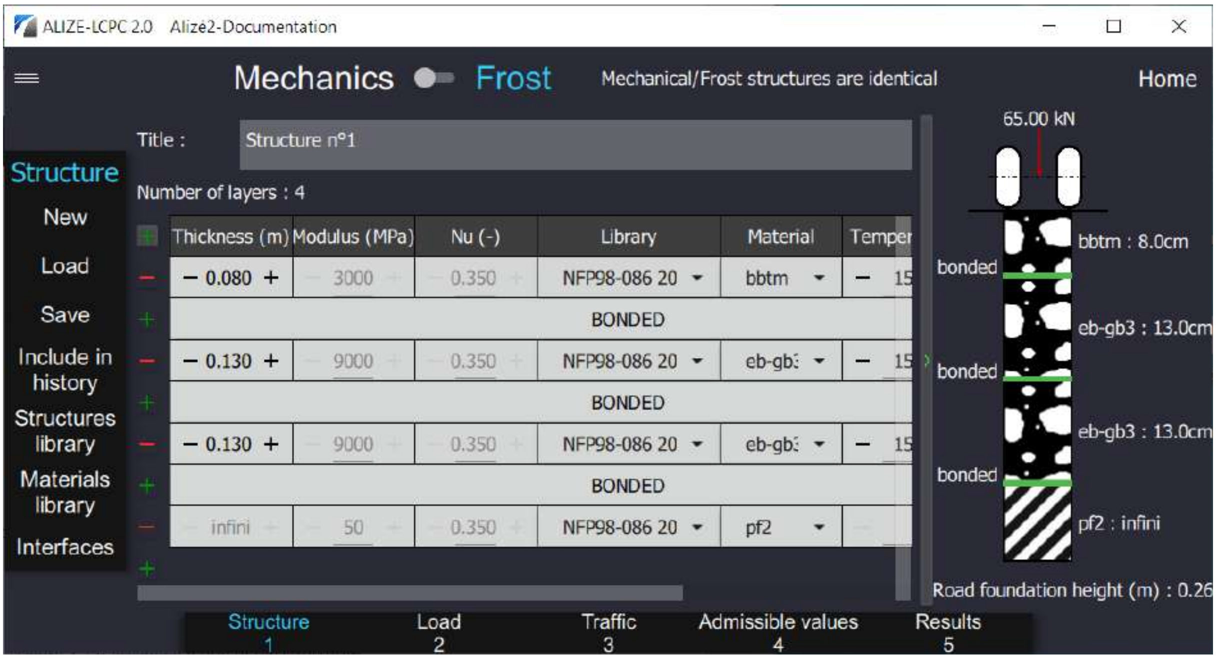


Figure 3-12: Overview of the Structure tab

➢ Title of the structure

The user is able to assign a title to the structure (Figure 3-13):

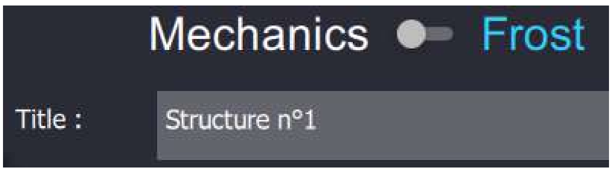


Figure 3-13: Assigning a title to the structure

The title assignment proves to be valuable in the event of a backup: the user has the potential to reuse a known road structure, in addition to testing various types of structures, etc.

This title also appears in the text file of the saved structure (Figure 3-14), as well as in both the user's log and mechanical report (see Section 3.2.5 Results tab):

structure no1.sru

```
Alize 2
Structure

07/02/2021 à 11:56:00
Structure n°1
Nombre de couches : 4
épaisseur   matériau    module   nu   type
0.080    bbtm    3000    0.350    bitum    N
0.130    eb-gb3  9000    0.350    bitum    N
0.130    eb-gb3  9000    0.350    bitum    N
infini   pf2 50   0.350    plateForme   NFP98
Nombre de variantes :    0
Code de variante (0: pas de variante, 1:
1

```

Figure 3-14: Extract of the backup structure file

➢ Data table

A predefined structure is presented, featuring 4 material layers whose characteristics have been collated in a table (Figure 3-15) that for each layer displays:

- its thickness;
- its module;
- its Poisson's ratio;
- the component material and the source library (by default, the library corresponding to the 2019 standard has been selected);
- its temperature;
- its frequency;
- its inclusion or not in the structure's base course.

+	Thickness (m)	Modulus (MPa)	Nu (-)	Library	Material	Temperature	Frequency	Foundation
−	− 0.080 +	3000	0.350	NFP98-086 20	bbtm	− 15 +	− 10 +	
+	BONDED							
−	− 0.130 +	9000	0.350	NFP98-086 20	eb-gb3	− 15 +	− 10 +	
+	BONDED							
−	− 0.130 +	9000	0.350	NFP98-086 20	eb-gb3	− 15 +	− 10 +	
+	BONDED							
−	infini	50	0.350	NFP98-086 20	pf2			

Figure 3-15: Data table of the Structure tab

Some values may be modified, while those that may not have been shaded.

❖ Modification of numerical values

A layer's thickness, temperature and frequency are all modifiable data elements. The + and – buttons positioned to the side of the values serves to raise or lower the base value by an interval of 1 cm (Figure 3-16), 1°C or 1 Hz, respectively.

Figure 3-16: Modification of a layer's thickness

These parameters may also be modified by entering their value using the keyboard. This input mode simply requires clicking the field, then entering the desired value, which is taken into account by pressing the *Return* key.

For temperatures and frequencies, the range of values extends respectively from -15°C to 60°C and from 2 to 30 Hz. A red message nonetheless notifies the user whether their standard values (i.e. 15°C, 10 Hz) have been modified.

The keyboard entry serves to assign a more precise value to the layer thickness (accurate to within a mm).

❖ Choice of materials library

In order to select the material composing each layer, Alizé2® proposes that the user start by choosing a materials library by means of clicking the *Library* column corresponding to the desired layer, after which the desired material can be indicated in the adjacent column.

Four options, three of which are materials libraries, are proposed (Figure 3-17):

- the first library is the 1998 catalogue;
- the second library stems from the 2011 Standard NF P98-086;
- the third library stems from the 2019 Standard NF P98-086 [1];
- *and the last one (other)* enables the user to define a material not included in a library.

Should the user choose *other* after selecting a library material, then the initial material parameters will be those of the library material, and the name will be *name_of material_preceding mod*.

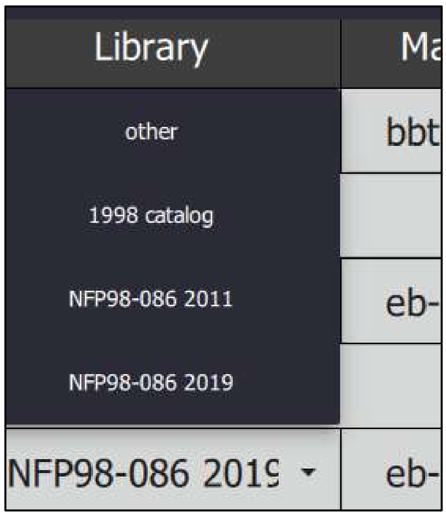


Figure 3-17: Choice of a materials library

By default, the library corresponding to the most recent standard in effect is selected, namely NF P98-086 from 2019 [1], which constitutes an update of the previous 2011 version.

❖ Choice of material

If a library is chosen, the list of its materials becomes available in the *Material* column. A material is automatically assigned to the layer based on the selected library.

To modify this choice, the user must click the material heading, thereby exposing a list of 5 material families (Figure 3-18, frame no. 1):

- bituminous materials;
- materials treated with hydraulic binder (MTHB);
- concretes;
- untreated gravels and soils (GNT/Soils);
- soils treated with hydraulic binder (STLH);

Figure 3-18: Choice of a family of materials and a specific material

By clicking the desired family, a list of materials appears on the right (Figure 3-18, frame no. 2), making it possible for the user to select the material corresponding to the given layer.

Since the families are not all of the same size, it may be necessary to use the mouse wheel to scroll down the list of all materials within a particular family. Click & drag is another option.

❖ Addition and deletion of a layer

Any layer can be deleted, provided however retaining at least two layers for the structure. The lower layer will always have an infinite thickness.

In order to delete a layer, simply click the red button with the "-" symbol placed relative to the layer, on the left side of the table (Figure 3-19).

To add a layer, simply click the green button with the "+" symbol placed relative to an interface, on the left side of the table (Figure 3-19). The new layer will then be inserted underneath the referenced interface.

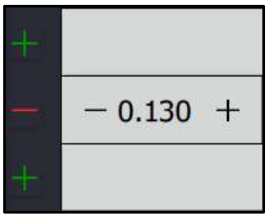


Figure 3-19: Addition and deletion of a layer

To add a surface layer, click the green "+" symbol placed relative to the table title row.

❖ Modification of an interface

The contact between two layers at the level of an interface may be of three types: bonded, semi-bonded, or sliding (Figure 3-20).

As a default, Alizé2® proposes a bonded contact. This parameter may be modified by clicking once or twice in the table on the targeted interface to obtain the preferred type. A third click returns to the initial contact type.

The structural diagram in the right-hand side panel (Figure 3-2) shows these various contact types through a distinct color scheme.

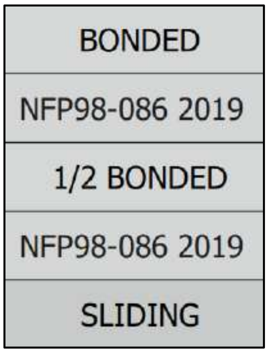


Figure 3-20: Modification of an interface

For further details, refer to Standard NF P98-086 2019 [1], Sections 3.1.20 to 3.1.23.

A help function on the nature of interfaces is also available in Alizé2® (see Section 3.1.4 Guides).

❖ Assignment of layers to the structure's base course

The last column of the table indicates the layers defining the pavement's base course. This information may then be used by Alizé2® to calculate the admissible values in the particular layers (see Section 3.2.4 Admissible values tab).

By default, Alizé2® assigns to the base course all intermediate layers lying between the surface layer and the ground, as well as all separating interfaces (Figure 3-21).

To define a new base course, the user must click in the box of the *Base course* column corresponding to the upper base course layer, and then in the box corresponding to the lower layer. The entire base course is then depicted in blue. This step can also be carried out in reverse (starting with the lower layer and proceeding to the upper layer).

Once the base course has been defined, the user may:

- define a new upper layer by clicking in the box of a layer located above the middle of the previously defined base course,
- define a new lower layer by clicking in the box of a layer located below the middle of the previously defined base course,

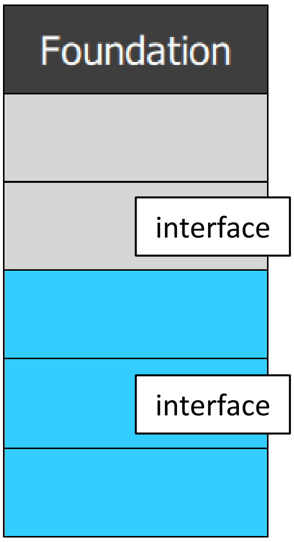


Figure 3-21: Assignment of layers to the base course

- only retain in the base course the middle layer, whenever the number of layers is odd, by clicking in the box corresponding to this layer,
- only retain in the base course the lower or upper layer by clicking in the box corresponding to this particular layer,
- delete the lone base course layer, if applicable, by clicking in the box corresponding to this single layer.

The platform is not included in the base course.

➢ Vertical *Structure* menu

The vertical menu on the left side of the screen serves to:

- request a **new structure**. Alizé2® would then delete the current structure to replace it with the default structure (containing four layers, as proposed when creating a new project);
- **retrieve a structure** whose characteristics have already been recorded in a file;
- **save** the characteristics of the current structure, in the Alizé2® and/or Alizé 1.5 format;
- record the various manipulations executed on the structure in a text file via the **Include in the log** function (see Section 3.1.5 Inclusion in the logInclusion in the);
- access the **structures library** (see Section 3.1.3 Libraries of structures and materials);
- access the **materials library** (see Section 3.1.3 Libraries of structures and materials);
- access the **interface guide** (see Section 3.1.4 Guides).

3.2.2 Load tab

The second tab serves to specify the load applied to the structure being designed (Figure 3-22).

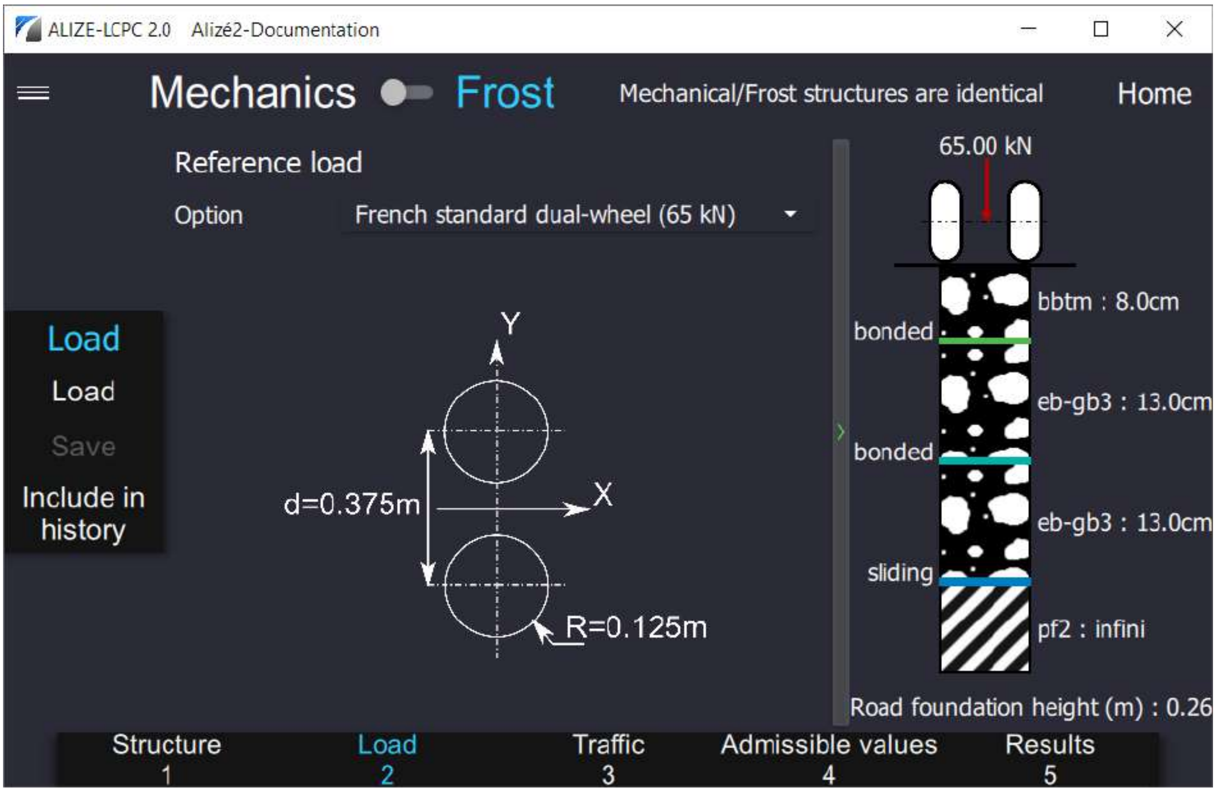


Figure 3-22: Overview of the Load tab

- Options

Three load options are proposed:

  - should the **standard French axle configuration** (as displayed by default and recommended in the 2019 standard [1]) be chosen, then the user need not enter any additional settings and may move directly to the next tab;
  - should the **Other axle configuration** option be chosen, the user is then asked to input (Figure 3-23) the values of two parameters from among the following three:
    - radius;
    - pressure;
    - weight per wheel.

    A relationship between these three parameters provides an automatic calculation of any of them from entry of the other two.

    The user then ticks the two boxes matching this choice before inputting the corresponding values.

    Lastly, the axle spacing for the given axle configuration must be entered.

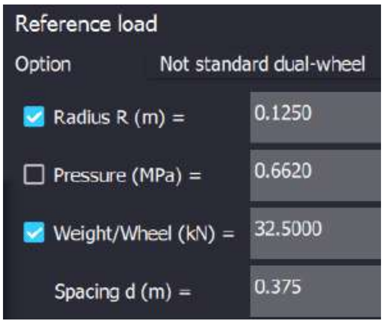


Figure 3-23: Input information of parameters in the "Other axle configuration" case

  - should the user select the **Isolated wheel** option, then the information to be provided is the same as above, minus the axle spacing.

For each option, a load configuration diagram is shown (Figure 3-24), with:

- X representing the direction of load movement;
- Y the transverse axis;
- R the radius of the wheelbase on the pavement;
- d the axle spacing of wheels for a given axle configuration.

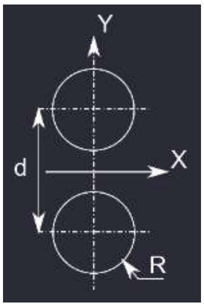


Figure 3-24: Diagram of an axle configuration

- Vertical *Load* menu

The vertical menu on the left side of the screen serves to:

- choose, via the **Load** option, another load configuration already recorded in a file;
- **Save** the current load configuration, in a .txt format;
- record the various manipulations executed on the load in a text file via the **Include in the log** function (see Section 3.1.5 Inclusion in the);

The diagram of the structural core is automatically updated should the wheel load value be changed.

3.2.3 Traffic tab

The third tab is devoted to defining the truck traffic (PL) volumes forecast for the structure undergoing design (Figure 3-25).

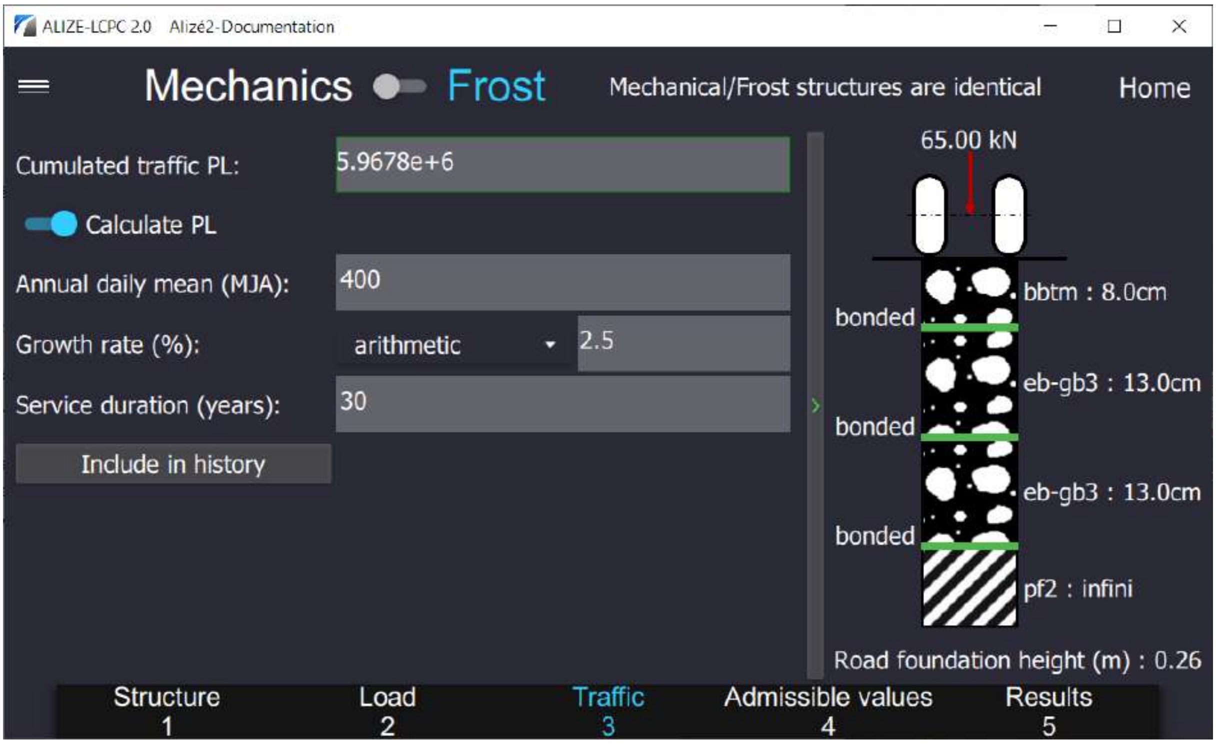


Figure 3-25: Overview of the Traffic tab

To proceed, the user must choose between two methods:

- either direct entry of the cumulative traffic counts, with such entry taking place in the single window field;
- or through calculation, after having reset the switch to the position **Calculate truck traffic** (Figure 3-26, red frame). The user is then required to input:
  - the annual average daily count of trucks traveling on this pavement;
  - the estimated annual rate of traffic increase, based on a selected progression mode: geometric or arithmetic;
  - the length of service, measured in years.

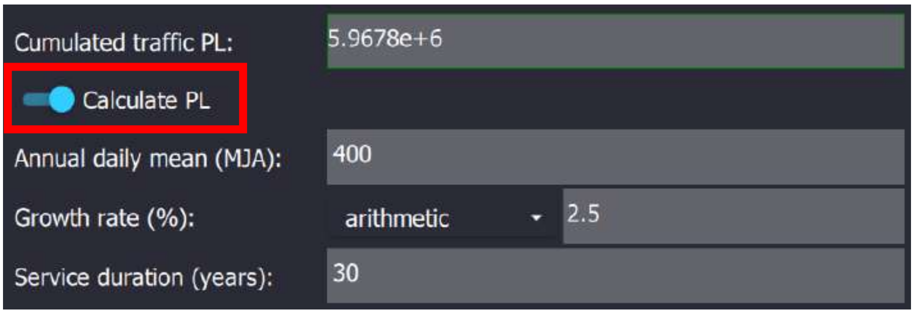


Figure 3-26: Calculation of truck traffic (PL)

Once all the fields have been filled, the calculated cumulative truck traffic is displayed in the upper field, whose thin edge initially red now turns green.

Lastly, the user may include these traffic characteristics into the log (see Section 3.1.5 Inclusion in the logInclusion in the).

3.2.4 Admissible values tab

The fourth tab serves to calculate the admissible values for each layer of the studied structure (Figure 3-27).

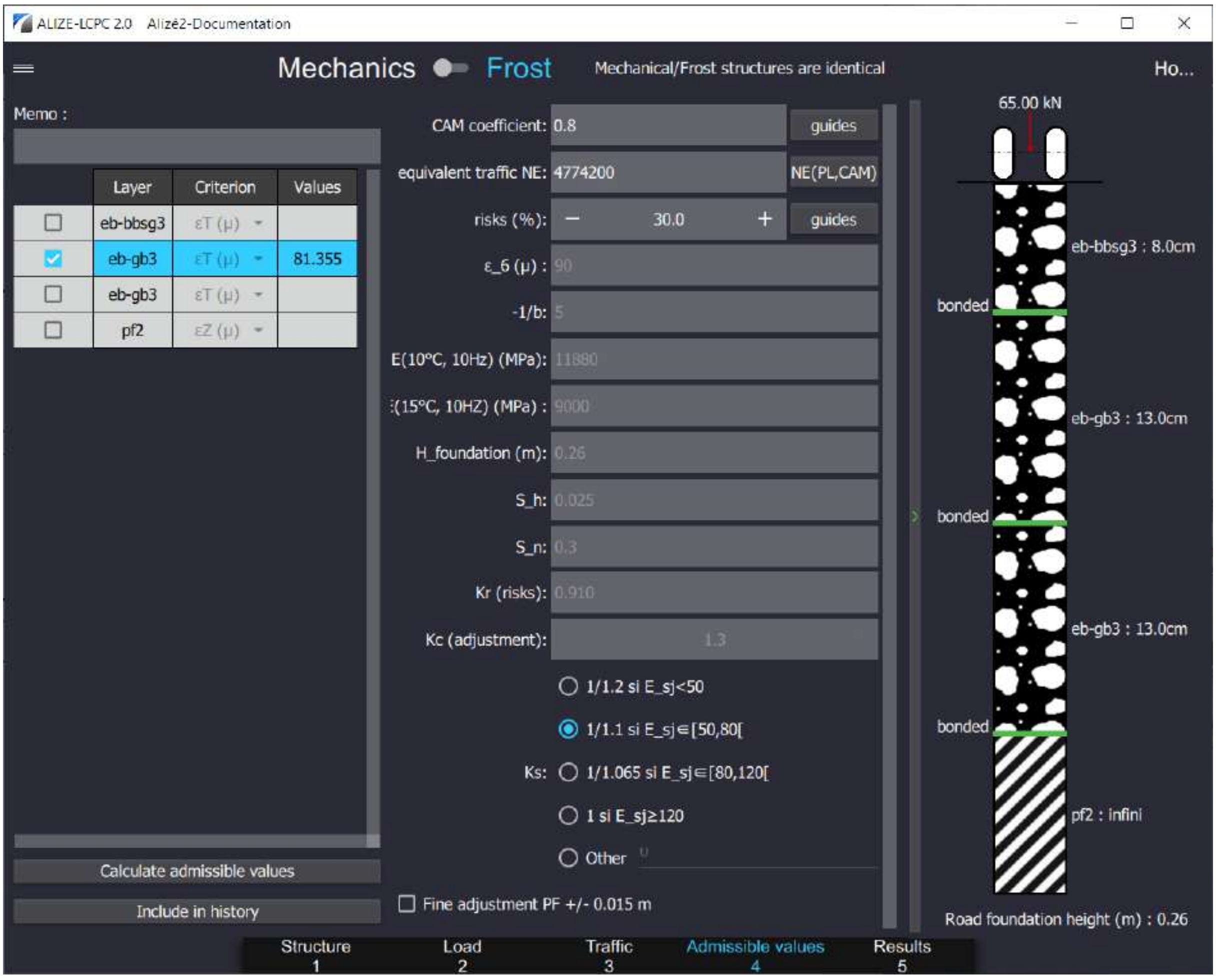


Figure 3-27: Overview of the Admissible values tab

In the upper left, a notes / comments zone can be used to recall any useful information, notably to explain the following steps (Figure 3-28):

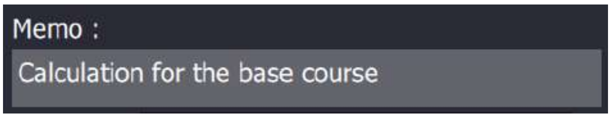


Figure 3-28: Annotation entry zone

The table below summarizes the various structural layers and the criteria underpinning the calculation of admissible values for each layer (Figure 3-29):

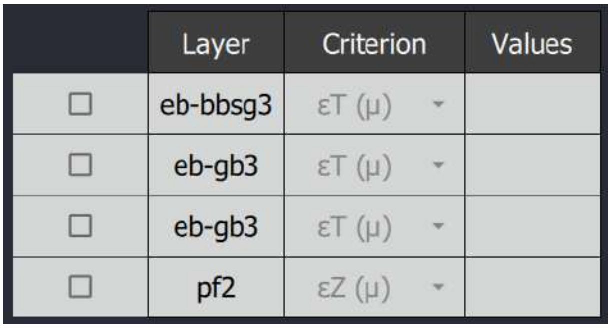


Figure 3-29: Table of the selection of layers subjected to an admissible values calculation

The boxes to be ticked enable selecting the layers whose calculation will be required, while the *Values* column will display the corresponding results. These criteria cannot be modified for materials stemming from an official library supplied by the software.

The admissible value (AV) calculation for a given layer requires:

- selecting in the table by ticking the corresponding box;
- entering the dedicated parameters in the right part of the screen (Figure 3-30).

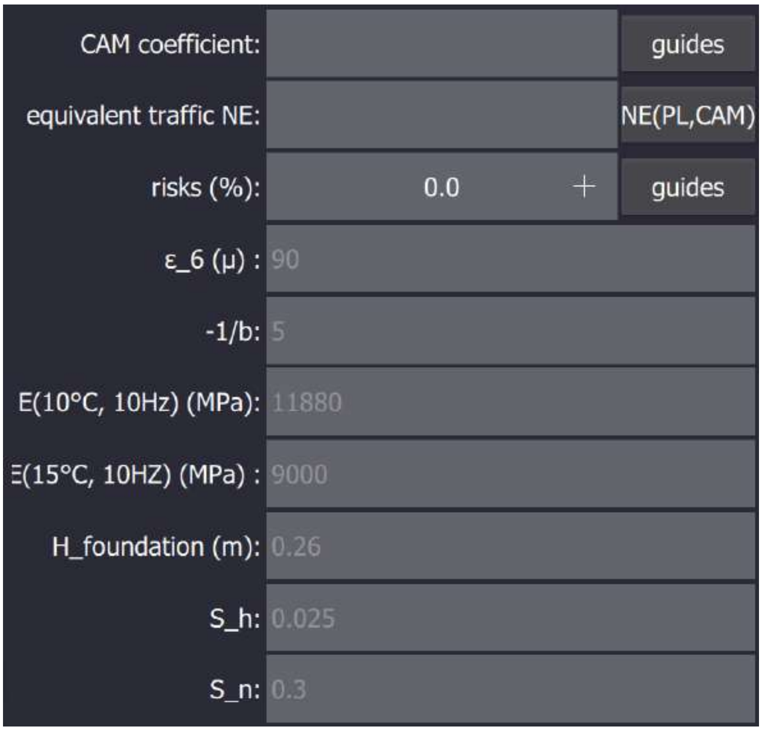


Figure 3-30: Table of the AV calculation parameters

Regardless of the criterion, the user is thus requested to input:

- AAC: by clicking the *guides* button specific to the field, a window opens and guides the user to calculating this coefficient (see Section 3.1.4 Guides). The computed value is then displayed in the corresponding field of Figure 3-30;
- "NE" equivalent traffic: by clicking the associated *NE* button *(truck traffic, AAC)*, its value is automatically calculated based on both the truck traffic indicated in the *Traffic* tab and the AAC value;

Next, the various parameters of the selected layers need to be defined on the basis of this criterion.

➢ Preparation of the calculation in the case of criterion ε_T

The user is now requested to input the risk (in %): by clicking the *guides* button specific to this field, a window opens and guides the user through the risk calculation (see Section 3.1.4 Guides). The calculated value is then displayed in the corresponding field of Figure 3-30;

For the AAC value, equivalent traffic and risk, it is possible to directly enter the value without clicking the corresponding buttons for this calculation step.

The parameter *H_base course* represents the cumulative height of bituminous material layers, excluding the wearing course, that compose the pavement base course. This parameter is used to calculate the *S_h* parameter value.

The value of *H_base course* is automatically calculated based on the given defined structure. This value is then used to calculate *S_h* should the *Automatic S_h calculation* option be activated (such is the default case). Otherwise, the user can choose the base course height to incorporate into the definition of *S_h*.

When modifying the base course thickness and should the *Automatic S_h calculation* option be activated, the admissible values are automatically recalculated by the software. This feature serves to avoid any errors, especially when thicknesses are modified in the *Results* part.

The following parameter values are determined by Alizé2® and cannot be modified if the material has been derived from an official library supplied by the software. Otherwise, the user will manually enter their value.

- *ε_6*: the average strain magnitude value leading to classical failure of the sample subjected to 10^6 cycles with a 50% probability (i.e. reduction of the initial force by 50%);
- *-1/b*, where b is the fatigue law slope of the bituminous material*;*
- the two Young's modulus values, one at 10°C the other at the layer temperature;
- *S_n* the standard deviation on the decimal logarithm of the number of cycles causing fatigue failure;
- *Kc* the calibration coefficient.

The coefficient of risk *Kr* will be calculated and displayed at the same time as the admissible values.

The user must ultimately enter the platform coefficient *Ks* (Figure 3-31):

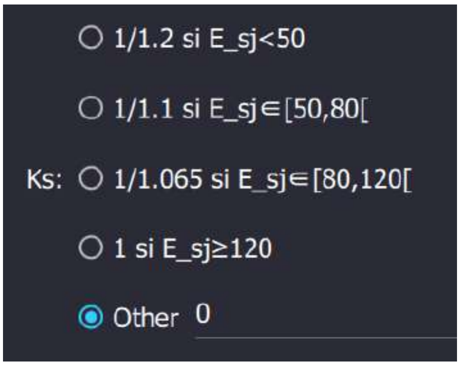


Figure 3-31: Determination of the coefficient Ks

This value is predetermined based on the stiffness modulus *E_sj* of the immediately underlying layer (or platform). Nonetheless, the user can still enter another value lying between 0 and 1.

Moreover, a box to be ticked (Figure 3-32) serves to incorporate the ability to comply with the thickness guideline prescribed at the time of implementation and thereby limit dispersion *S_h*:

Figure 3-32: Incorporation of the thickness guideline

For additional details on the various parameters, please refer to French Standard NF P98-086 2019 [1] or else to the technical guide [3].

- Preparation of the calculation in the case of criterion σ_T

  In the same way as in the case of criterion ε_T, the user must enter the values of the various parameters, in particular by defining the following fields:

  - *σ_6*: the average stress magnitude value leading to a life cycle duration in bending fatigue of 10^6 cycles, with a 50% probability on a material aged 360 days or more;
  - *1/Kd*, where *Kd* is the coefficient of discontinuity for materials treated with hydraulic binders.

  The parameter *ε_6* and Young's modulus values at various temperatures do not affect these materials.

- Preparation of the calculation in the case of criterion ε_Z

  For an untreated gravel (GNT) type of layer or the platform, the AAC value and NE equivalent traffic are to be calculated in the same manner as before.

  As regards parameters A and b, their values are automatically calculated by Alizé2® according to the criteria contained in Standard NF P98-086 2019 [1], as defined in Sections 8.1 and 8.7. The value of A depends on the NE equivalent traffic, while b remains constant with a value of -0.222.

- Calculation of admissible values

  Once the above parameters have been input for a given layer, the calculation of its admissible value becomes possible. Provided inputs have been entered for all layers, the admissible values applicable to the specified structure may be calculated in a single click for one or more layers.

  Simply tick the boxes corresponding to the targeted layers located in front of the table (Figure 3-29), then click at the bottom the *Admissible values calculation* button. The values are displayed in the last column of the table for the selected layers.

Here once again, the user may include both the characteristics of the various layers and the calculated admissible values in the log (see Section 3.1.5 Inclusion in the log).

The user may elect to launch the calculation after entering the parameters of each layer. It is not necessary to initiate a calculation for each layer.

The *Admissible values calculation* sub-module also makes it possible to perform a calculation without having first defined the structure.

3.2.5 Results tab

Once the previous tabs have been completed, Alizé2® proposes a final tab summarizing the set of available results (Figure 3-33):

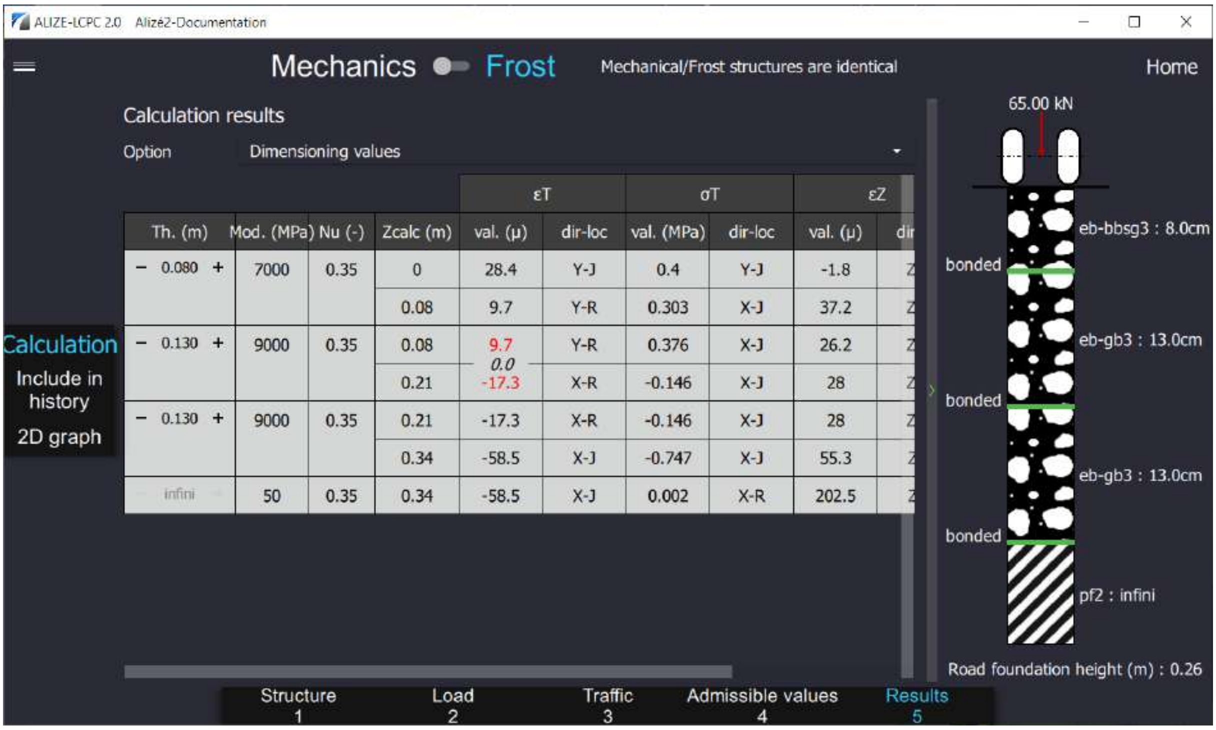


Figure 3-33: Overview of the Results tab

Results are presented in the form of tables compiling the design values, as well as the stresses or strains depending on the choice made by the user from among the three options on the dropdown list (Figure 3-34):

Figure 3-34: Choice of the results presentation option

A graphics tool available in the vertical menu on the left side also shows these results in the form of superimposable 2D curves.

➢ Results tables

❖ Design values table

The first 3 columns of the table recall the thickness, Young's modulus and Poisson's ratio of each layer. For the subsequent columns, each row corresponding to a layer is divided into two, with the upper part providing the values calculated at the upper layer boundary while the lower part indicating the values calculated at its lower boundary.

The *Zcalc (m)* column contains the depth from the pavement surface.

The next two columns *εT* and *σT* present the minimum values of both strains ε and stresses σ in the transverse direction T.

Lastly, the last two columns *εZ* and *σZ* display the maximum values of strains ε and stresses σ in the vertical direction Z.

In the transverse direction T, a negative value corresponds to extension, whereas in the vertical direction Z, a positive value represents compression.

Each result (εT, σT, εZ, σZ) is expressed in two columns (Figure 3-35), the first (labeled val.) indicating the value of the magnitude calculated and the second (dir-loc) providing both the direction and location of this extreme point (whether the minimum according to T or the maximum by Z).

The direction is expressed along the X, Y and Z axes, while the vertical position is expressed relative to the load application, i.e. R for a calculation under the center of the wheel and J for a calculation under the middle of the axle configuration.

The admissible value calculated previously for each selected layer is reported in black italics, between the values of results for both the upper and lower parts of the layer, in the column corresponding to the design criterion.

Should the design values remain less than the admissible values in absolute terms, then they are displayed in green; otherwise, the display color is red.

εT	
val. (µ)	dir-loc
28.4	Y-J
9.7	Y-R
9.7	Y-R
81.4	
-17.3	X-R
-17.3	X-R
46.5	
-58.5	X-J

Figure 3-35: Minimum strain values εT, admissible values, direction and location of the calculation for the 3 upper layers

All calculated values displayed in red lead to invalidating the design produced. It then becomes necessary to modify the structure so that it is capable of resisting the projected load.

In remaining in the *Results* tab, the user can also modify the thicknesses of one or more layers in the table, by means of the "+" and "–" buttons.

When modifying thicknesses in the *Results* tab, the admissible values are automatically recalculated.

❖ Stress value tables

When the user chooses the *Stresses* option (Figure 3-34), a new field labeled *Profile* appears just below (Figure 3-36):

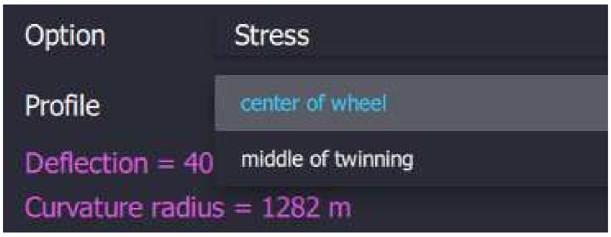


Figure 3-36: Choice of profile for the stress value calculations

Depending on the selected profile, the values appearing in the table thus correspond to the result of a calculation under either the center of the wheel or the middle of the axle configuration (should one have been chosen in the *Load* tab). The values of deflection and radius of curvature, indicated in color above the table, also get automatically updated as a function of the chosen profile.

The last 6 columns of the table show the values of the stress tensor σ, both above and below the layer, just like for the design values.

The values along the X, Y and Z axes correspond to the tensile and compressive stresses, whereas the values in the XY, YZ and ZX planes correspond to the shear stresses.

❖ Strain value tables

The table of strains is laid out in a strictly similar fashion to that of the stresses.

➢ 2D curves

The results may also be viewed graphically in a separate window by clicking the *2D curves* menu in the vertical menu.

The left side, in a retractable and resizable panel, lists the available curves, while on the right side the graphics component displays the values of results (horizontal axis) vs. depth (vertical axis) (Figure 3-37):

Figure 3-37: Initial window of the 2D curves display

❖ Available curves

The data available on the list in the left panel are presented in the following order:

- the admissible values calculated;
- the 4 design values *EpsiT*, *SigmaT*, *EpsiZ* and *SigmaZ*;
- the strains in the xyz reference under the center of the wheel (and under the middle of the axle configuration, in the case where one has been chosen);
- the stresses in the xyz reference under the center of the wheel (and under the middle of the axle configuration, should one have already been chosen).

A given admissible value is identified by its *AV* label followed by the number of the layer for which it was calculated during the previous step as well as the selected calculation criterion. As such, *AV2 EpsiT* corresponds to the curve depicting the admissible value calculated for layer no. 2 according to the strain *εT* criterion.

Since by definition all admissible values are constant, their corresponding curves reflect vertical segments over the height of the particular layer.

Only the admissible values previously calculated in the dedicated tab appear in the list of available curves.

In the case of a load composed of an isolated wheel, Alizé2® outputs:

- six calculation results for the strains: wheel EpsiX, wheel EpsiY, wheel EpsiZ, wheel EpsiXY, wheel EpsiYZ, and wheel EpsiZX;
- six results for the stresses: wheel SigmaX, wheel SigmaY, wheel SigmaZ, wheel SigmaXY, wheel SigmaYZ, and wheel SigmaZX.

In all, twelve curves are thus available.

In the case of an axle configuration, Alizé2® combines these calculation results with those obtained in the middle of the axle configuration, thus bringing the total number of available curves to 24.

By ticking the boxes on the left side, the user is thereby deciding on the curves to be displayed for the current structure from among the available admissible values, as well as the strain or stress calculation results (Figure 3-38):

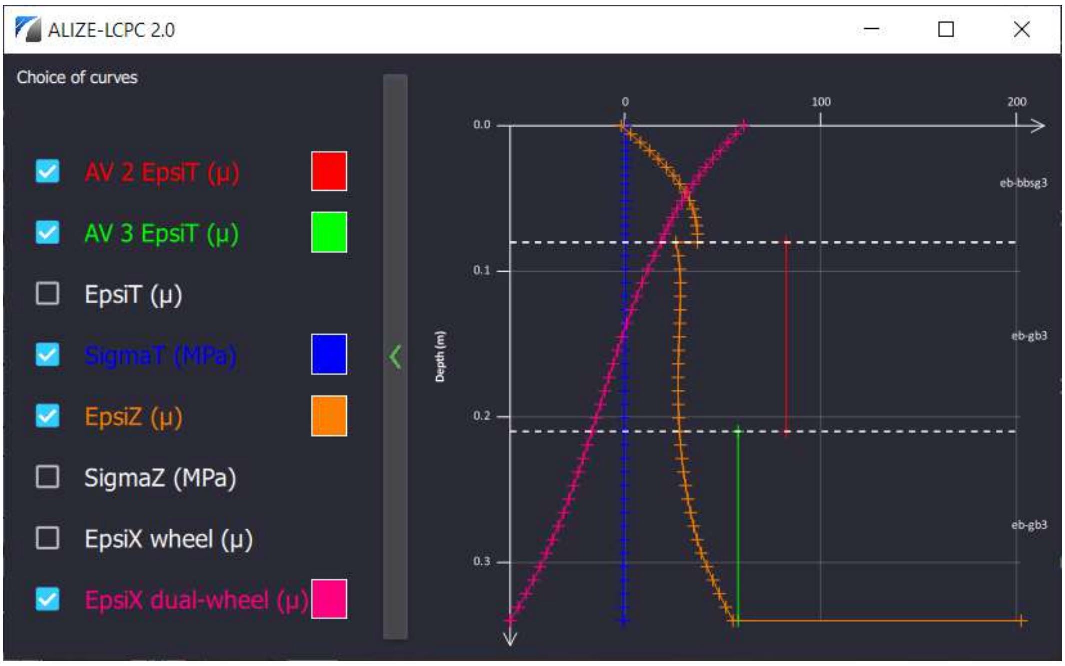


Figure 3-38: Display of the curves of results and admissible values

❖ Ergonomics

As of the first curve displayed on the graph, white horizontal dashed lines appear to separate the various layers, with respect to their thickness; the name of the corresponding material is then displayed on the right side.

As the curves get selected over time, the scale of the graph is instantaneously adjusted to enable the full display of all curves.

Several techniques allow the user to better visualize the curves, namely by:

- showing the window as a full screen (having font sizes automatically grow);
- using the mouse wheel to zoom in and out of a specific region;
- using the mouse wheel to zoom in and out on an axis;
- moving the graph by means of clicking & dragging.

Each ticked curve is assigned a color in accordance with a given order: red, green, blue, orange, pink, etc. Should a curve be unticked, the color assigned will be ascribed to the next curve selected.

It is possible to modify the color of a curve by clicking the sample rectangle corresponding to the curve in the left part.

The following window now appears (Figure 3-39):

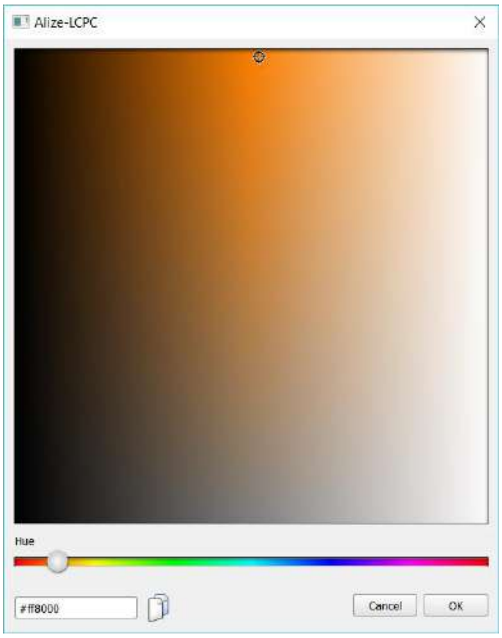


Figure 3-39: Modification of the color of a curve

To define the new color, the user must first activate the horizontal ruler in order to select the main color scheme and then move the cursor over the colored rectangular part to refine the lighting pattern.

More simply, the user may enter the hexadecimal value corresponding to the desired color in the input and display rectangle, at the bottom left. The code naturally includes a # symbol to begin. After, the first two characters correspond to the level of red, the next two to the level of green and the last two to the level of blue (RGB coding), which serves to define 256 levels per component. This code can then be copied and pasted from one curve to another.

- Mechanical report

The Project menu of the *Results* tab contains a new option entitled *Mechanical report* (Figure 3-40), making it possible to generate a summary document.

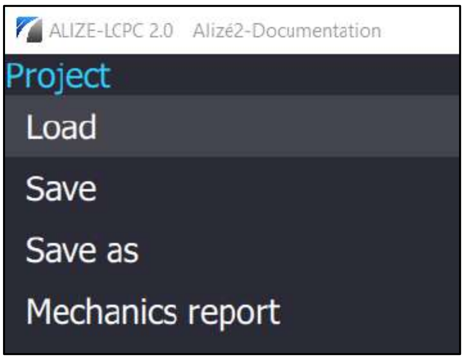


Figure 3-40: Access to the mechanical report via the Project menu

A window enables customizing this report (Figure 3-41) by means of proposing that the user choose the options and results sought to be incorporated.

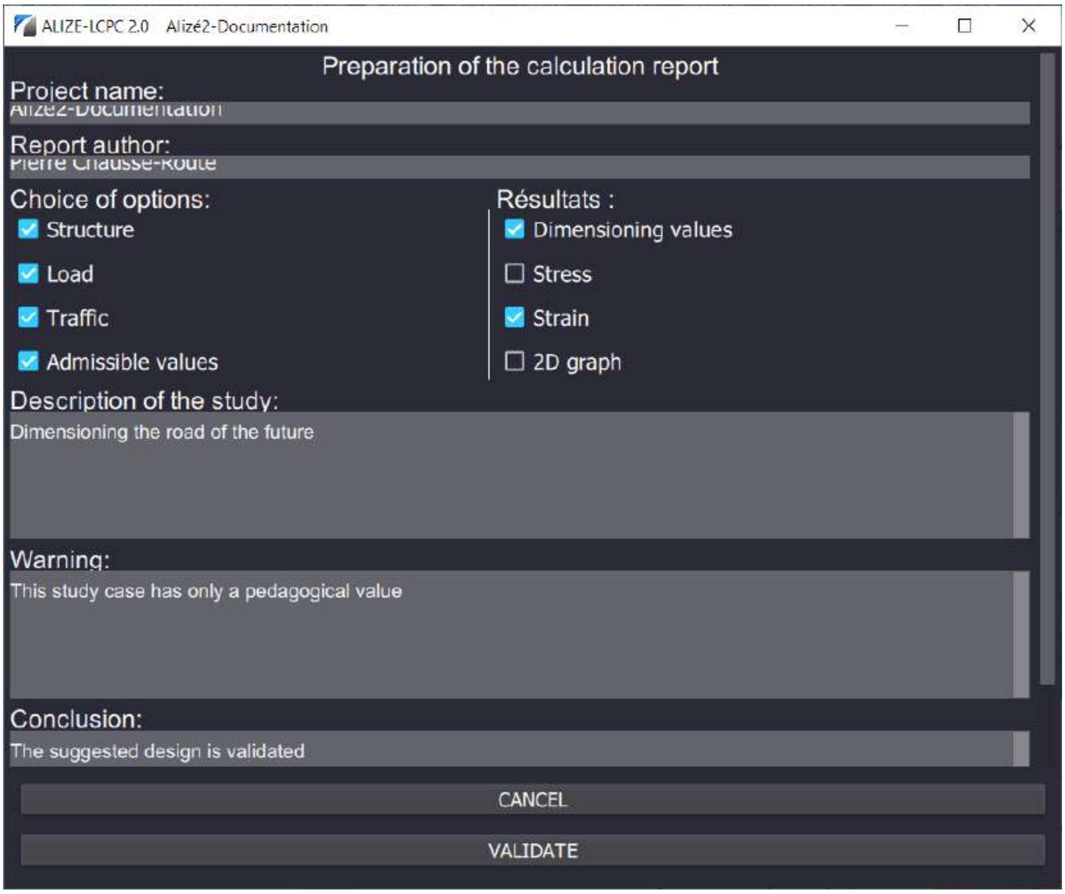


Figure 3-41: Configuring the mechanical report

The user can thereby elect to integrate the primary characteristics of the design derived from the *Structure*, *Load*, *Traffic* and *Admissible values* tabs, and then the various results obtained: values of design, stresses, strains and 2D curves.

Moreover, the user can customize the report printout by freely entering a certain amount of information, for example:

- an individual file name. By default, Alizé2® proposes the name *Calculation_Note_date_time*;
- a description of the study;
- a warning or observation relative to the study;
- a conclusion.

By clicking *Validate*, the report is generated in a pdf format and automatically saved in the dedicated project folder.

In the file name, it is important to only use those characters authorized by Windows.

In particular, the characters \ /: * ? " < > | are prohibited; also, it is strongly advised not to use spaces, accents and the % sign.

The report can only be generated if the project location has been defined locally or else via a network drive identified by a letter and address of the type Z:\....
The syntax "*name_server*\..." is to be avoided.

- If the user has ticked *Structure*, then the data stemming from the *Structure* tab and integrated into the report (Figure 3-42) are:
  - the list of layers and their thicknesses;
  - Young's modulus;
  - Poisson's ratio;
  - the library and material used in each layer;
  - temperature and frequency;

  The condition of interfaces between the layers is also indicated.

1 Structure

Thickness (m)	Modulus (MPa)	Nu (-)	Library	Material	Temp. (°C)	Freq. (Hz)
0.08	7000	0.35	NF P98-086 v2019	eb-bbsg3	15	10
Bonded						
0.13	9000	0.35	NF P98-086 v2019	eb-gb3	15	10
Bonded						
0.13	9000	0.35	NF P98-086 v2019	eb-gb3	15	10
Bonded						
Inf.	50	0.35	NF P98-086 v2019	pf2	15	10

Figure 3-42: Example of a portion of the mechanical report pertaining to the Structure tab

- Should the user have ticked *Loading*, then the data stemming from the *Load* tab and integrated into the report (Figure 3-43) are as follows:
  - the type of load: isolated wheel, French standard or other axle configuration;
  - radius;
  - pressure;
  - weight per wheel;
  - and in the case of an axle configuration (either French standard or other), the axle spacing.

2 Load

French standard twinning

Radius (m) = 0.125

Pressure (MPa) = 0.662

Weight/Wheel (kN) = 32.5

Spacing (m) = 0.375

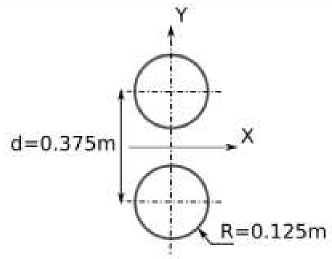


Figure 3-43: Example of a portion of the mechanical report pertaining to the Load tab

- If the user has ticked *Traffic*, the data stemming from the *Traffic* tab and integrated into the report (Figure 3-44) are:
  - the cumulative truck traffic;

  and should this cumulative traffic have been calculated:
  - the annual daily average;
  - the kind of rate of increase (arithmetic or geometric) and its value;
  - the length of service life.

3 Traffic

Heavy load cumulative traffic: 5.96775e+06

Annual daily mean: 400

Arithmetic growth rate: 0.025

Length of service: 30

Figure 3-44: Example of a portion of the mechanical report pertaining to the Traffic tab

- Lastly, had the user ticked *Admissible values*, the data stemming from the *Admissible values* tab and integrated into the report (Figure 3-45) are:
  - summary table of the admissible values calculated, along with the associated criterion;
  - the full set of values used to perform the calculation for each layer.

4 Admissible values

Layer #	Material	Criterion	Calculated value
2	eb-gb3	εT	82.443
3	eb-gb3	εT	57.930

Layer 2

CAM: 0.80 NE: 4774200 Risk: 0.30

ε_6: 90.000 -1/b: 5.000 E(T,f)(MPa): 11880

E(Eq,f)(MPa): 9000 S_h: 0.015 S_n: 0.300

Kr: 0.922 Kc: 1.300 Ks: 0.909

Figure 3-45: Example of a portion of the mechanical report pertaining to the Admissible values tab

- If the user had ticked the three *Design values*, *Stresses* and *Strains* boxes, then the data presented would be respectively those of the design values table, stress value table and strain value table, all of which have been generated under the *Results* tab.

- If the user had ticked *2D curves*, then the report would display the available curves from among those relative to the four design values *EpsiT*, *SigmaT*, *EpsiZ* and *SigmaZ* (Figure 3-46).

The ultimate curves displayed using the *2D curves* functionality are not included in the mechanical report.

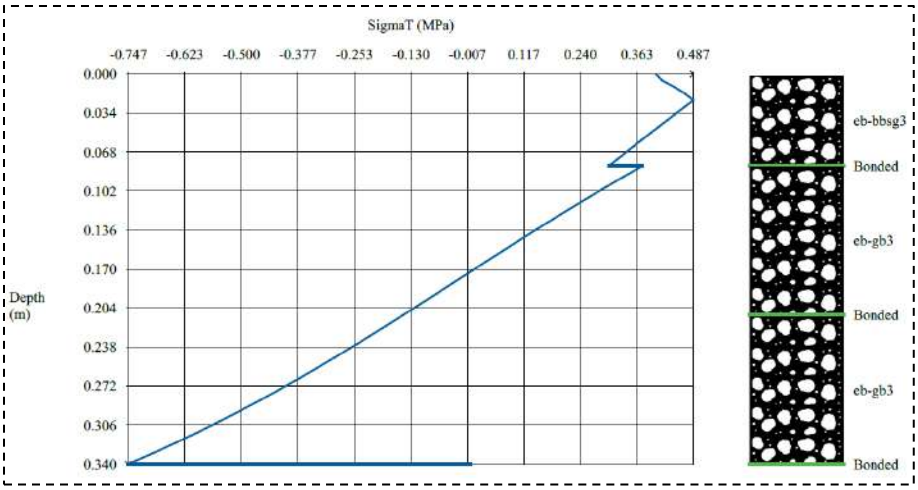


Figure 3-46: Example of a 2D curve from the mechanical report

4 Frost verification

The *Frost verification* part of Alizé2® is not a stand-alone module, but rather a distinct part integrated with:

- the *Road design* module, within both the *Standard* sub-module (see 3.2 Standard Standard mechanical design) and *Expert* sub-module;
- the aeronautical module.

The frost verification function serves to ensure, to the extent allowed under Standard NF P98-086 (2019), that the designed structure will be capable of withstanding the freeze-thaw cycles.

4.1 Verification of a road pavement

4.1.1 General remarks

Based on an appropriately designed road structure, frost verification may begin upon activating the switch located at the top of the screen (Figure 4-1):

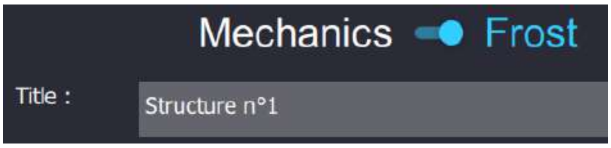


Figure 4-1: Mechanical-Frost switch and name of the structure

---

A frost verification may be conducted independently of any preliminary mechanical design.

- Name of the structure

  The name assigned to the structure in the Mechanical part can be found in the *Frost verification* part (Figure 4-1).

- Steps

  As was the case for the mechanical design, the window at the bottom of the screen contains, in the form of tabs, the calculation steps to be followed in sequence (Figure 4-2):

Figure 4-2: Tab bar of the Standard sub-module –frost verification part

- structural specification;
- indication of weather conditions;
- calculation of the admissible frost quantity *Qpf*;
- the frost verification, along with the results curves.

➢ Structural diagram

The right part of the screen displays the diagram of the studied structure in the retractable panel, along with its various layers (Figure 4-3).

As opposed to the Mechanical part, the layers are separated by gray-colored interfaces, regardless of their condition: bonded, semi-bonded, or sliding. The top of the Zpf platform is colored blue.

Each layer is illustrated by both its type of material and thickness, in a graphical display identical to the Mechanical part.

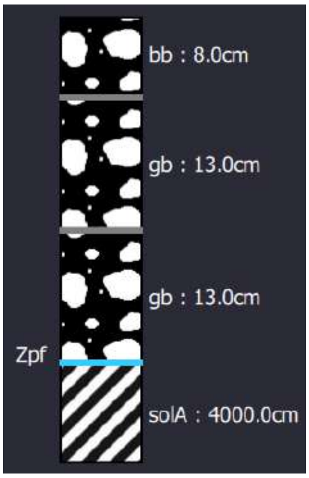


Figure 4-3: Structural diagram

➢ The LCPC-Setra model temperature curves

Another panel to the left of the pavement structural diagram displays three LCPC-Setra model temperature graphs (Figure 4-4):

- top: the initial temperatures vs. depth curve;
- middle: the curve of temperatures at the pavement surface (Z = 0 m) vs. time;
- bottom: the curve of temperatures at the base of the pavement (Z_{base} = Zpf + 40 m) vs. time.

The values displayed on the top diagram, as well as the base depth on the bottom diagram, get automatically updated if the top of the Zpf platform is modified in the structure table.

Just like the structural diagram, this retractable panel always remains available and independent of the tab being consulted.

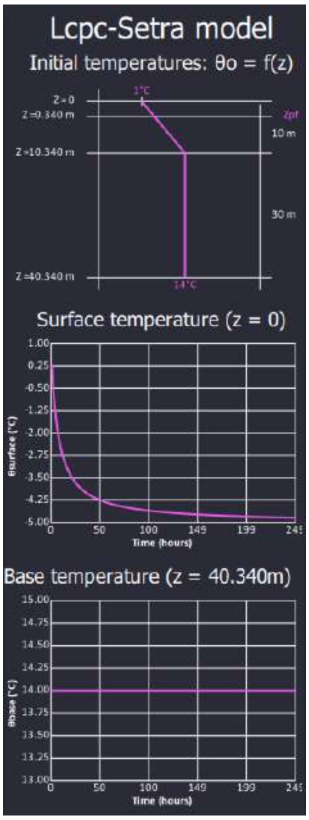


Figure 4-4: LCPC-Setra model temperature curves

4.1.2 Structure tab

This first tab summarizes the data from the studied structure generated by the Mechanical part, by means of adapting to the frost verification context (Figure 4-5):

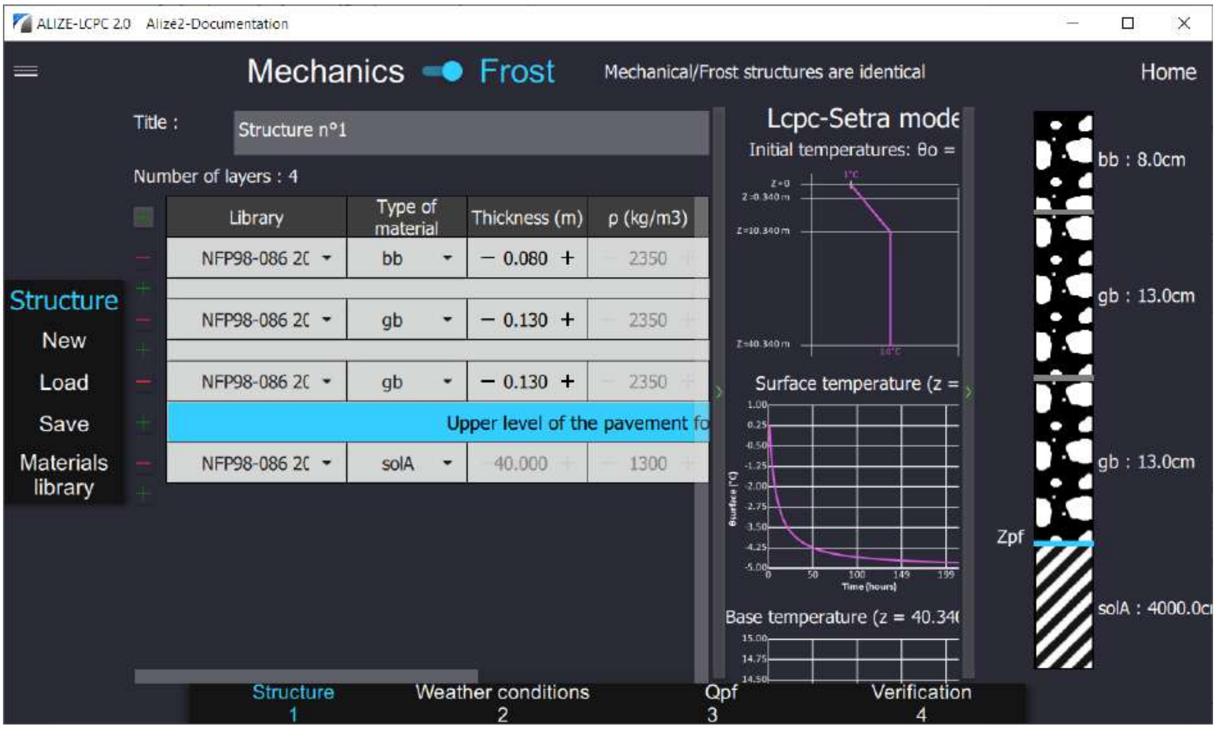


Figure 4-5: Overview of the Structure tab

➢ Data table

In order to demonstrate the thermal characteristics of the structure, the data table (Figure 4-6) presents for each layer:

- the library used;
- the type of material within this library;
- the layer thickness;
- the dry mass density ρ selected for the material;
- the mass water content W;
- the factors λ of thermal conductivity: *λng* in the unfrozen state and *λg* in the frozen state.

Library	Type of material	Thickness (m)	ρ (kg/m3)	W (%)	λng (W/m.°C)	λg (W/m.°C)
NFP98-086 201	bb	0.080	2350	1.0	2.0	2.1
NFP98-086 201	gb	0.130	2350	1.0	1.9	1.9
NFP98-086 201	gb	0.130	2350	1.0	1.9	1.9
Upper level of the pavement foundation Zpf						
NFP98-086 201	solA	40.000	1300	32.0	1.1	1.8

Figure 4-6: Data table associated with the Structure tab

Some values can be modified while those that cannot are shaded.

❖ Libraries

The libraries are the same as those used in the Mechanical part (see 3.1.3 Libraries of structures and materials).

❖ Types of material

The frost verification relies on the mechanical and thermal characteristics of the families of materials composing the pavement under study, without requiring any specific knowledge of the material used.

Moreover, once the structure has been recorded in the Mechanical part, the switch to frost verification triggers the automatic assignment of a material type to each layer, as displayed in the second column of the table.

This assignment step takes place according to a correspondence rule between the materials and their type; the rule itself is found in the specific materials library (see below).

❖ Top of the Zpf platform

As opposed to the Mechanical part, the table does not provide information on the condition of the interfaces; the rectangular zone between the layers enables the user, by clicking on it, to define the Zpf position on top of the platform.

The overall platform thickness is set at 40 m. Consequently, the thickness of the lowest layer is automatically adjusted should the platform top be modified, in order to account for the thicknesses of the included layers.

The core diagram is automatically updated should Zpf be modified, as are the values plotted on the LCPC-Setra model temperature graphs.

❖ Modification to the thicknesses

The operations here is identical to that in the Mechanical part (see 3.2.1 Structure tab).

Changing values in the Frost part has an effect on the Mechanical part since the two structures are coupled.

❖ Modification to the types of materials

Modifying a type of material in the Frost part produces a modification to the material displayed in the Mechanical part. Should a material type in the Frost part be capable of combining several materials in the Mechanical part, the first material on the list would be selected and then appear in the Mechanical part table. For example, according to Figure 4-7, if the user were to change the type from *bb* to *gb*, the material displayed in the Mechanical part would be *eb-gb2*.

Conversely, if the user were to modify a material in the Mechanical part, its type would automatically be updated in the Frost part.

A structural modification in the Frost part would necessitate, when switching to the Mechanical part, viewing one of the first four tabs (*Structure* or other) before proceeding to the *Results* tab.

If the user were to create an *Other* material in the Mechanical part, Alizé2® would automatically create an *Other* material in the Frost part, thus requiring its configuration. The opposite is also true, since *Other* does not possess any predetermined mechanical or thermal property.

If the user were to switch from the Frost part to the Mechanical part, while there deleting or adding a layer or creating a new structure, and then seek to carry out a frost verification, the platform position would have to be verified first.

- Modification to the choice of library

  Modifying the choice of library on the Mechanical side causes this choice to be acknowledged on the Frost side and moreover generates a material change in accordance with the step-by-step operation indicated in the previous item - *Modification to the types of materials*.

  The principle works the same from the Frost part to the Mechanical part.

- Vertical Structure menu

As is the case in the Mechanical part, a vertical menu located on the left of the screen proposes various options, namely:

- the *New*, *Load* and *Save* options, which are also listed in the Mechanical part, operate in the same manner (see their description in Section 3.2.1 Structure tab).

- the *Materials library* option, which enables visualizing the set of properties useful to material frost verification, depending on their type and various technical benchmarks (Figure 4-7):

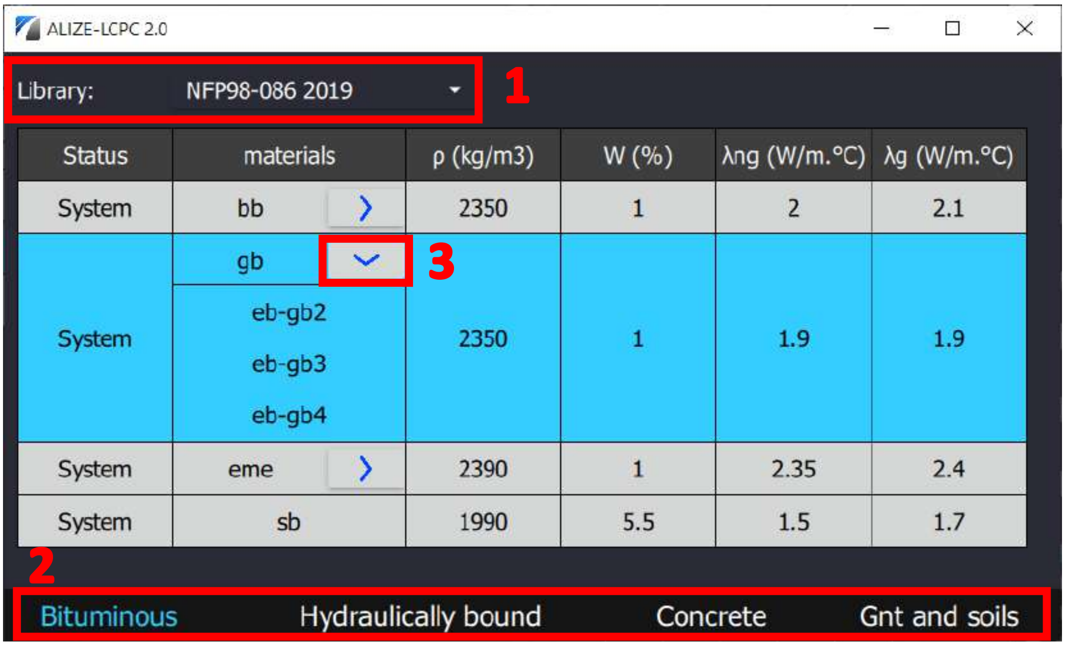


Figure 4-7: Materials library – Frost verification part

The user starts by choosing the benchmark (red frame no. 1), then the family of materials in the lower bar tab (red frame no. 2). The table appearing shows in its second column the various types of materials used in the *Frost verification* part.

By clicking the blue arrow to the right of the type of materials (red frame no. 3), the table then exposes the list of names of materials composing this particular type. In the illustration below (Figure 4-7), the selected type *gb* contains the array of materials *eb-gb2*, *eb-gb3* and *eb-gb4*.

4.1.3 Weather conditions tab

This tab serves to both configure the calculation of the admissible atmospheric frost index *Ia* and choose or enter a reference frost index *Ir* (Figure 4-8):

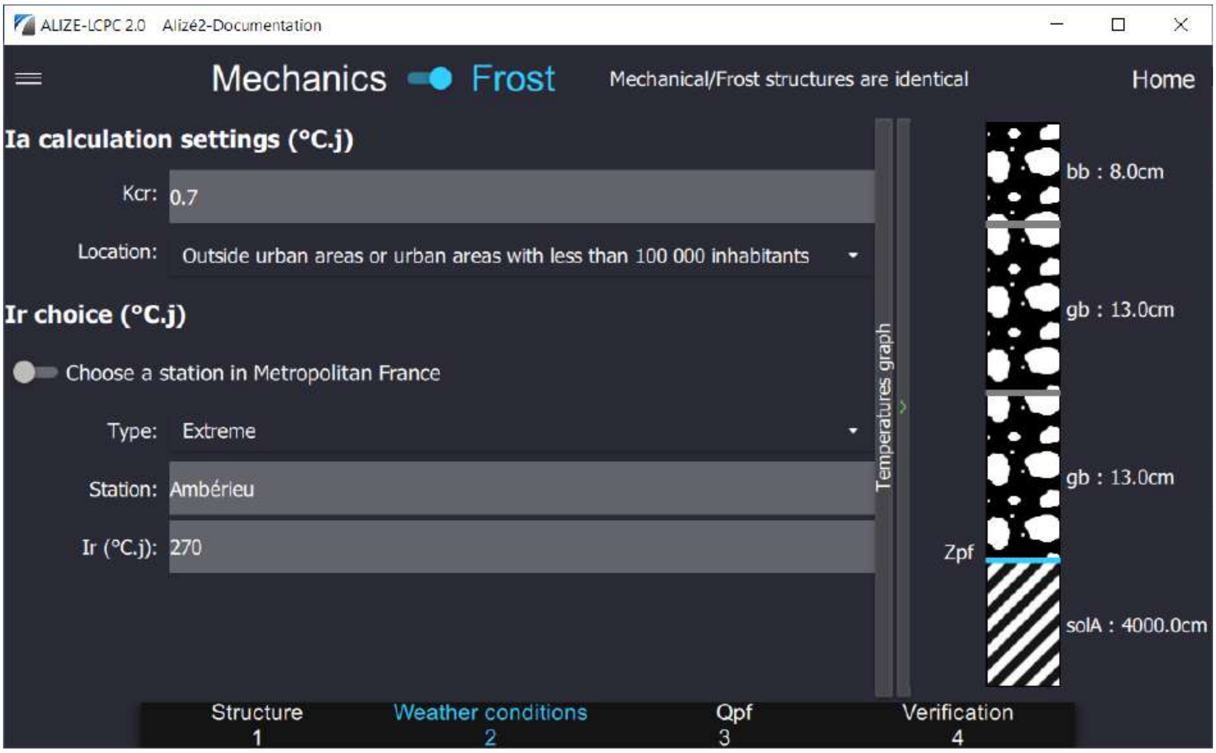


Figure 4-8: Overview of the Weather conditions tab

In Alizé2®, *Iatm* is the atmospheric frost index value, while *Ia* is the admissible atmospheric frost index value.

- Calculation of *Ia*

The *Ia* calculation depends, among other things, on the coefficient *Kcr* and the location (relative to size of the population) of the pavement to be designed (Figure 4-9):

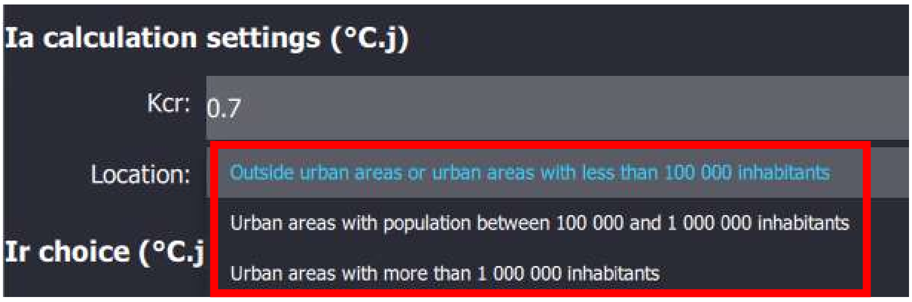


Figure 4-9: Parameters of the Ia calculation

Depending on the locational choice made by the user (red frame), the *Ia* calculation formula will be adapted by means of a weighting coefficient.

For further information on *Kcr* and the weighting coefficient related to the localization step, refer to Standard NF P98-086 2019 [1], Section 6.2.4.

➢ Choice of *Ir*

The reference frost index *Ir* may be set by either the user or the choice of a referenced weather station.

❖ User entry

The option of user entry entails (Figure 4-10):

- choosing the type of winter: *Exceptional* or *Harsh, yet unexceptional*;
- naming the weather station;
- indicating the reference frost index *Ir*.

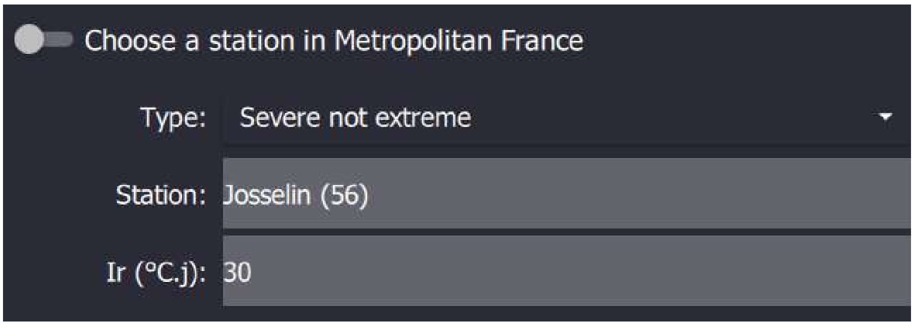


Figure 4-10: Definition of Ir by the user

❖ Choice of a weather station

The user also has the ability to choose a weather station after moving the *Choose a station in Metropolitan France* switch to right. A table of stations located in Metropolitan France then appears along with their reference frost index values, initially sorted by department number (Figure 4-11):

Figure 4-11: Choosing a weather station for the definition of Ir

After selecting the type of winter (i.e. *Exceptional* or *Harsh, yet unexceptional*) in the dropdown list above the table and then the preferred station, the value of *Ir* used for verification is displayed in the banner positioned below the table.

To quickly find the station adapted to the particular situation, it is possible, by clicking the column headings, to sort the table in either increasing or decreasing order by department number, station name or frost index value.

4.1.4 Qpf tab

This tab serves to determine the admissible frost quantity at the level of the Zpf platform (Figure 4-12):

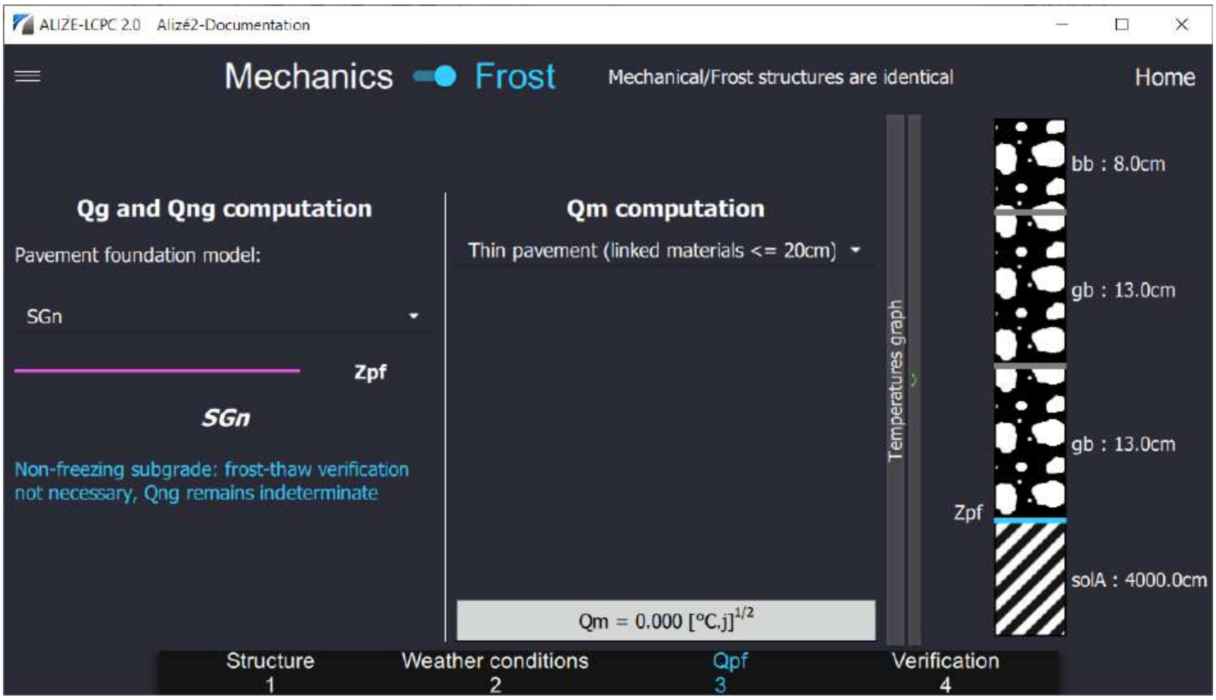


Figure 4-12: Overview of the Qpf tab

This tab contains two parts (in addition to the side panels):

- the left part enables calculating the admissible frost quantities *Qg* for the frost-sensitive materials and *Qng* for the non-frost-sensitive materials;
- the right part serves to calculate the quantity of mechanical frost *Qm*.

➢ Calculation of *Qg* and *Qng*

By default, the proposed platform is not frost-sensitive (*SGn*), although the user has the option of selecting another configuration from among the various ones presented (Figure 4-13):

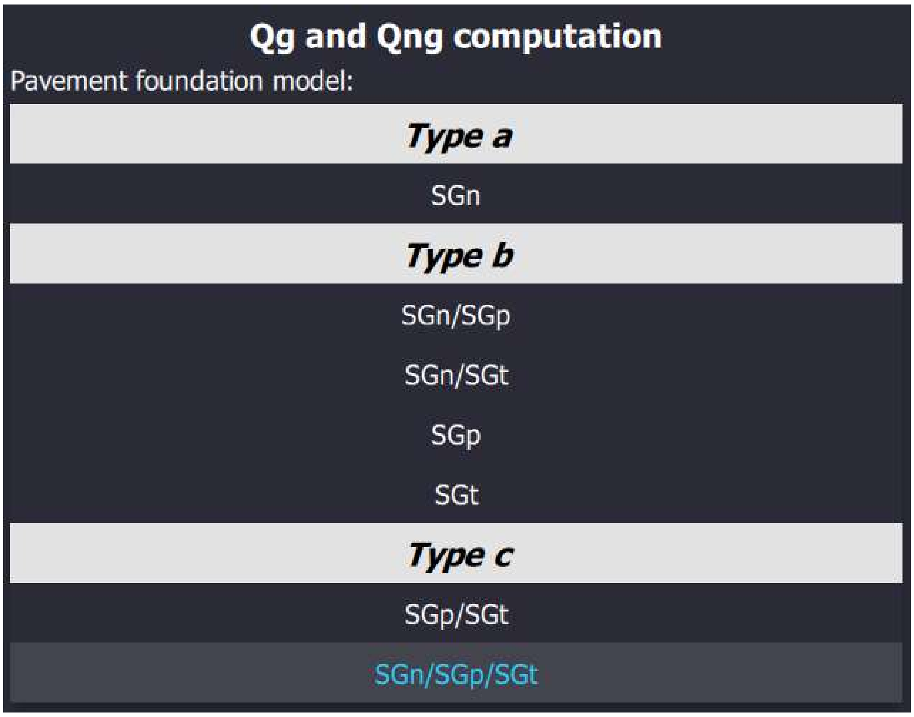


Figure 4-13: Selection of the platform configuration

The types of configurations (*a*, *b*, *c*) and frost sensitivities (*SGn*, *SGp*, *SGt*) of the materials are described in Standard NF P98-086 2019 [1], Section 6.2.1.

❖ *Type a* configuration – *SGn*

According to this configuration, since the platform is not frost sensitive, frost verification is unnecessary. Alizé2® is unable to calculate the parameters Qg and Qng.

❖ *Type b* configurations – *SGn/SGp* and *SGn/SGt*

In the case of *SGn/SGp* (Figure 4-14), the user must enter:

- the height *Hn*;
- whether this material has been treated with hydraulic binders (MTHB);
- the category of material constituting the non-frost-sensitive layer;
- the slope *p* specific to the relatively frost-insensitive layer.

In the case of *SGn/SGt*, the parameters to be input are identical, with the slope *p* this time being relative to the highly frost-sensitive layer.

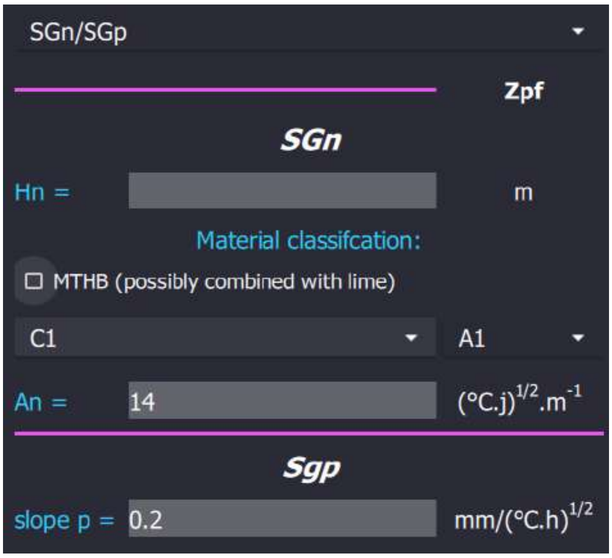


Figure 4-14: SGn/SGp configuration settings

The coefficient *An* is automatically calculated by Alizé2® on the basis of the material classification.

❖ *Type b* configurations – *SGp* and *SGt*

In the case of *SGp* (Figure 4-15), the user must input the slope *p* relative to the relatively frost-insensitive layer, while in the case of *SGt*, the slope *p* relative to the highly frost-sensitive layer.

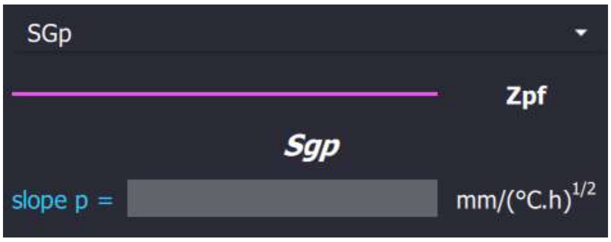


Figure 4-15: SGp configuration settings

❖ *Type c* configurations – *SGp/SGt* and *SGn/SGp/SGt*

In the case of *SGp/SGt* (*Figure 4-16*), the user must input:

- the height *Hp*;
- the slope *p* specific to the relatively frost-insensitive layer;
- whether this material has been treated with hydraulic binders (MTHB);
- the category of material constituting the relatively frost-insensitive layer;
- the slope *p* relative to the highly frost-sensitive layer.

The coefficient *Ap* is automatically calculated by Alizé2® on the basis of the material classification.

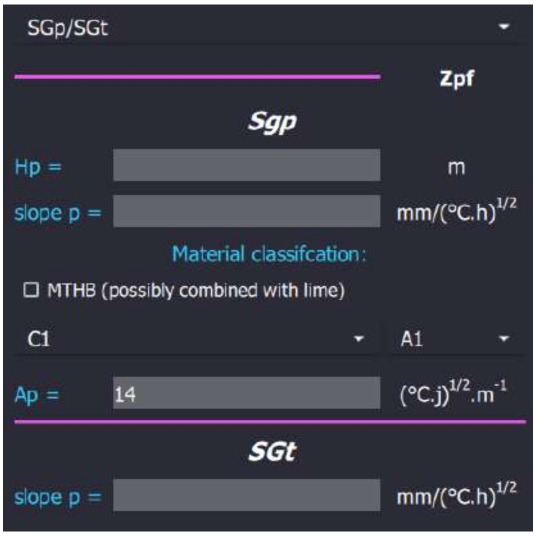


Figure 4-16: SGp/SGt configuration settings

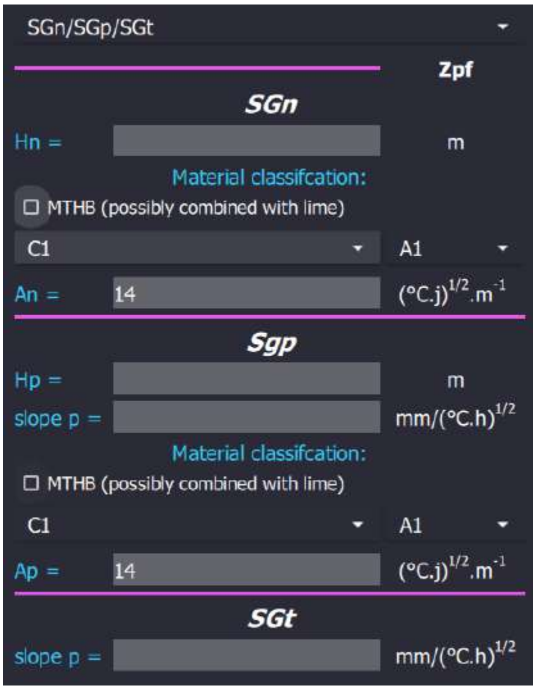


Figure 4-17: SGn/SGp/SGt configuration settings

In the case of *SGn/SGp/SGt* (*Figure 4-17*), the user must also input the following:

- the height *Hn*;
- if this material has been treated with hydraulic binders (MTHB);
- the category of material composing the non-frost-sensitive layer.

The complete set of information relative to both the *An*, *Ap* coefficients and the slope *p* of frost swelling test is given in Standard NF P98-086 2019 [1], Appendix C.

After inputting the various parameters corresponding to the chosen configuration and with the exception of configuration *Type a – SGn*, the user can observe at the bottom of the window the values of *Qng* and *Qg* that Alizé2® has automatically calculated (*Figure 4-18*):

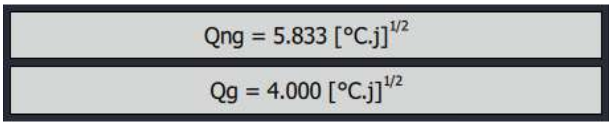


Figure 4-18: Display of the Qng and Qg calculation results

- Calculation of *Qm*

Calculation of the quantity of mechanical frost *Qm* associated with the structure depends on the total thickness of the bound layers. The user must thus select the configuration of the pavement under study (*Figure 4-19*):

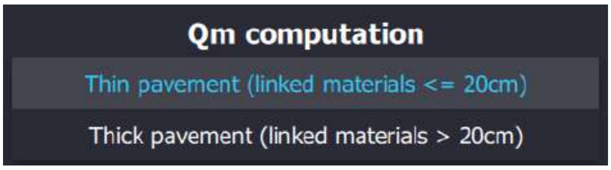


Figure 4-19: Choice of pavement configuration for the Qm calculation

❖ Case of relatively thin pavement

According to the 2019 Standard NF P98-086 (Paragraph 6.2.1.5), when the total thickness of the bound layers is less than or equal to 20 cm, *Qm* equals zero.

❖ Case of a thick pavement

If the total thickness of the bound layers is greater than 20 cm, the user must proceed with its data entry or calculation.

- In the event of a direct entry of thickness *e*, *Qm* is calculated instantaneously and equals ten times *e*.
- In the event of Alizé2® calculating this thickness *e*, the user must move the switch to the right (*Figure 4-20*) in order to choose, in accordance with the guidelines provided in the 2019 Standard NF P98-086:
  - the layer where the most heavily penalizing mechanical criterion is to be applied;
  - the nature of this criterion, in terms of stress σ_T or strain ε_T.

  The *Calculate* button serves to initiate the calculation by using the structure defined in the Mechanical part. This algorithm is explained in the 2019 Standard NF P98-086 (Paragraph 6.2.1.5).

  For information purposes, the results of each calculation iteration are presented in a table (*Figure 4-20)* whose last row is selected for the *Qm* calculation.

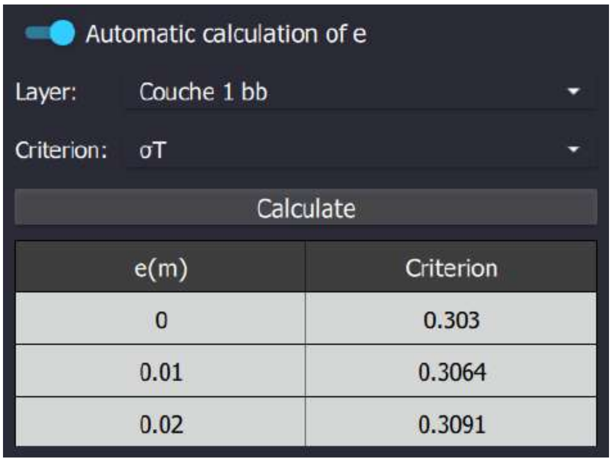


Figure 4-20: Calculation of e according to both the selected layer and criterion

In both cases, the value of *Qm* is updated at the bottom of the window:

Figure 4-21: Display of the result of the Qm calculation

- Calculation of *Qpf*

  For the *Type a* configuration – *SGn*, no calculation is made of the frost quantity *Qpf*.

  For the other configurations, the admissible frost quantity *Qpf* at the pavement support platform level equals the sum of quantities *Qg*, *Qng* and *Qm* calculated previously. This value is automatically displayed and updated at the top of the window (*Figure 4-22*):

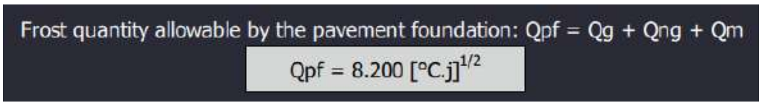


Figure 4-22: Display of the Qpf calculation

4.1.5 Verification tab

This tab serves to execute, thanks to the formulae indicated in the 2019 Standard NF P98-086, the calculation of the admissible atmospheric frost index *Ia*.

The comparison of *Ia* with the reference index *Ir*, obtained in the *Weather conditions* tab, then allows issuing either a positive or negative conclusion on the frost verification. The verdict appears in either green or red, respectively, in the banner above the tabs (Figure 4-23):

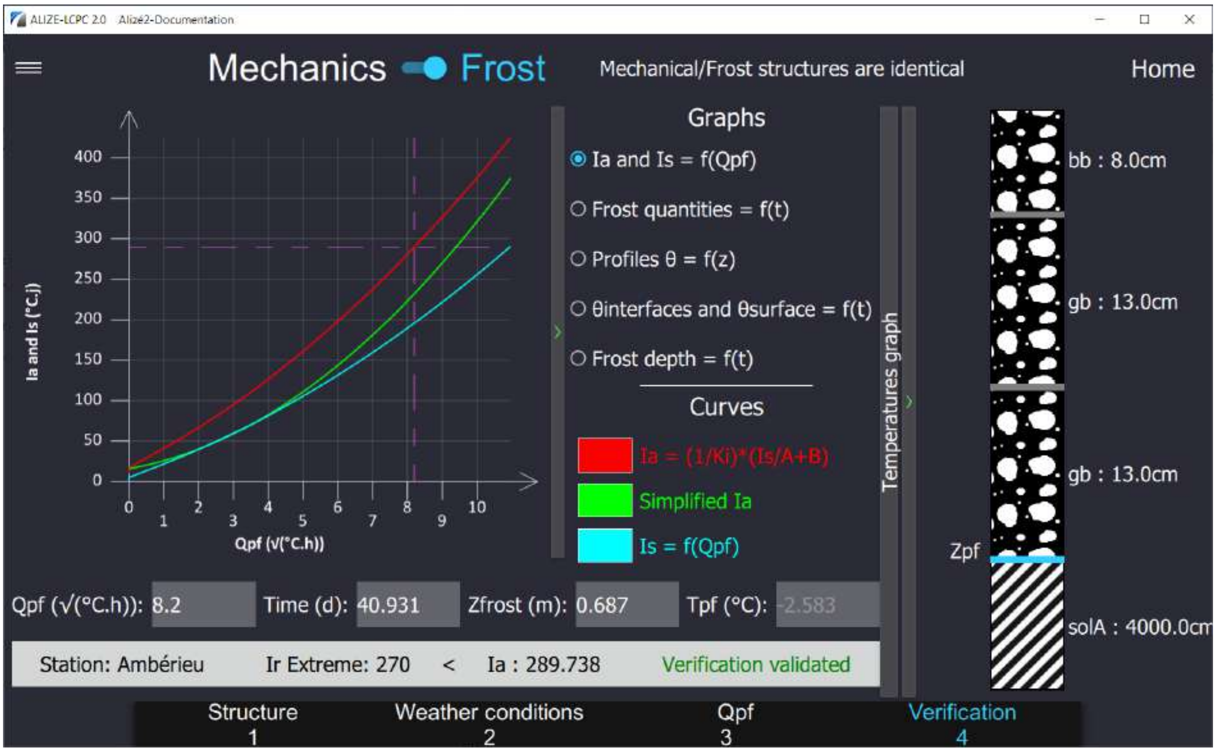


Figure 4-23: Overview of the Verification tab

Lying above this banner is a display of the four values stemming from the calculation based on data contained in the first three tabs.

When an admissible frost quantity value *Qpf* at the platform level has been calculated based on the *Qpf* tab, the user accesses the values of *Time* (in days), frost depth *Zfrost* (m) and temperature *Tpf* (°C) also at the platform level should the frost quantity have reached this value at this particular level.

Moreover, this tab serves to perform more customized calculations. It is thereby possible to directly enter the admissible frost quantity value *Qpf* for the given structure. Parameters *Time*, *Zfrost* and *Tpf* are then recalculated. The step-by-step operations are identical whether or not the parameters *Time* and *Zfrost* are modified: any values not entered are automatically recalculated.

	Should any one of the three values *Qpf*, *Time* or *Zfrost* be modified, the representation of this value is automatically updated on the graphs.
	If any one of the three values *Qpf*, *Time* or *Zfrost* has been modified, the fact of quitting the *Verification* tab instantaneously triggers the re-initialization of all these three fields.
	Since the *Time* value has been capped at 60 days, the other fields are reduced to 0 should this value be exceeded. In this case, no conclusion can be drawn regarding the frost verification.

Besides the frost verification outcome, this tab offers the possibility of consulting various graphs associated with the study:

- Graph of the admissible index value curves of both atmospheric frost *Ia* and pavement surface *Is* vs. the frost quantity relayed to the platform.

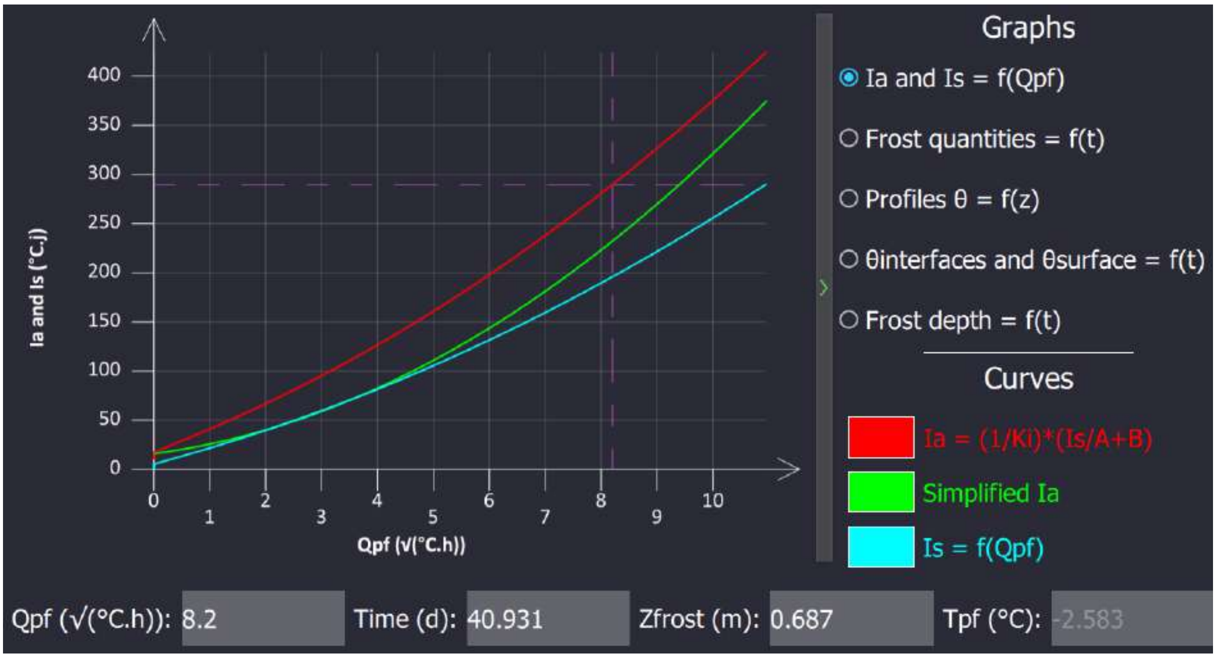


Figure 4-24: Index values Ia and Is vs. Qpf curves

On Figure 4-24 above:

- The red curve provides the values of *Ia* vs. *Qpf* according to the formula: *Ia* = (1/Ki)*(Is/A+B). More specifically, the graph identifies, by use of dashed lines, the maximum admissible value of *Qpf* and the corresponding *Ia* value;

- The green curve yields the values of simplified *Ia* (via a calculation explained in the 2019 Standard NF P98-086, Appendix H) vs. *Qpf*;
- The teal curve shows the values of *Is* vs. *Qpf*.

The color of curves may be modified by clicking the color square in the legend.
For further details, see Section 3.2.5 Results on the 2D curves.

➢ Graph of the frost quantity vs. time curves

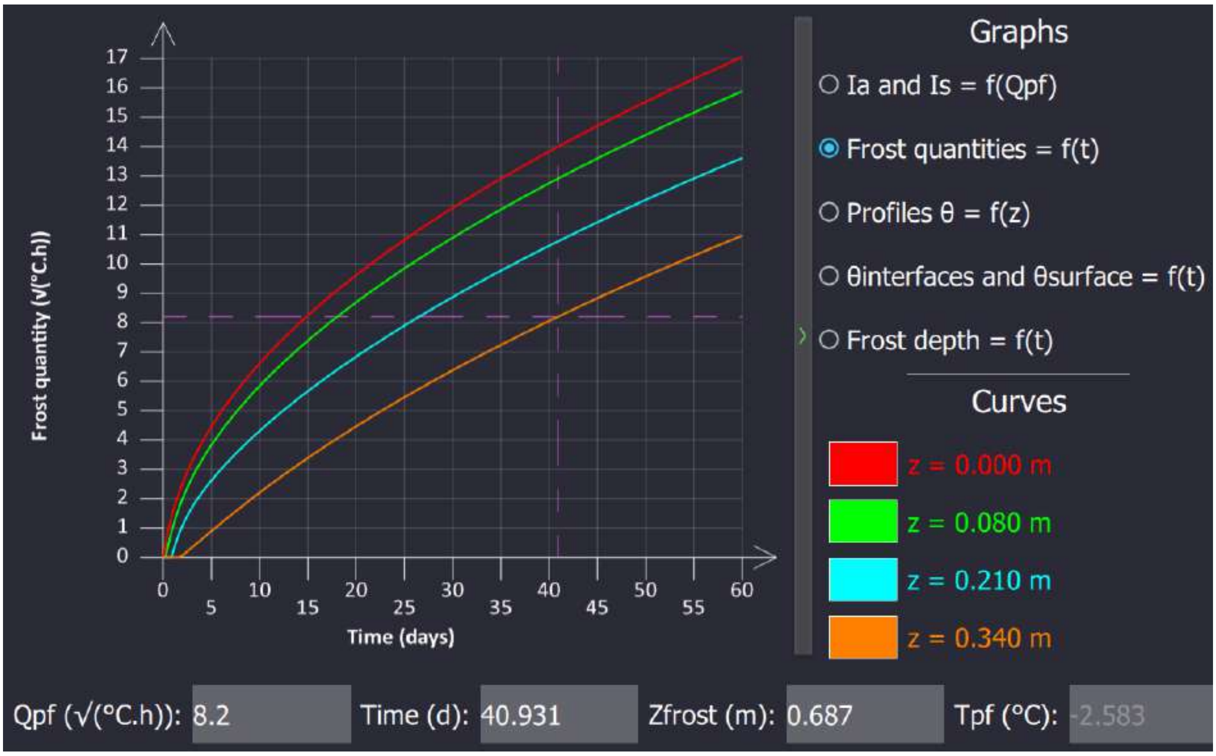


Figure 4-25: Curves of the frost quantities at various depths vs. time

A frost quantity curve is plotted for each depth corresponding to a layer interface (Figure 4-25). In the present example:

- at the ground surface level: Z = 0.000 m – red curve
- at the 1st interface level: Z = 0.080 m – green curve
- at the level of the subsequent interfaces: Z = 0.210 m – teal curve
- at the platform level: Z = 0.340 m – orange curve

The graph identifies, by means of dashed lines, the maximum admissible value of Qpf at the platform level (orange curve) as well as the corresponding value, expressed in days. These values are also indicated in the fields displayed below the graph. In the case of *Figure 4-25*: 8.2 for Qpf and 40.931 for time.

➢ Graph of the vertical temperature profiles at different times

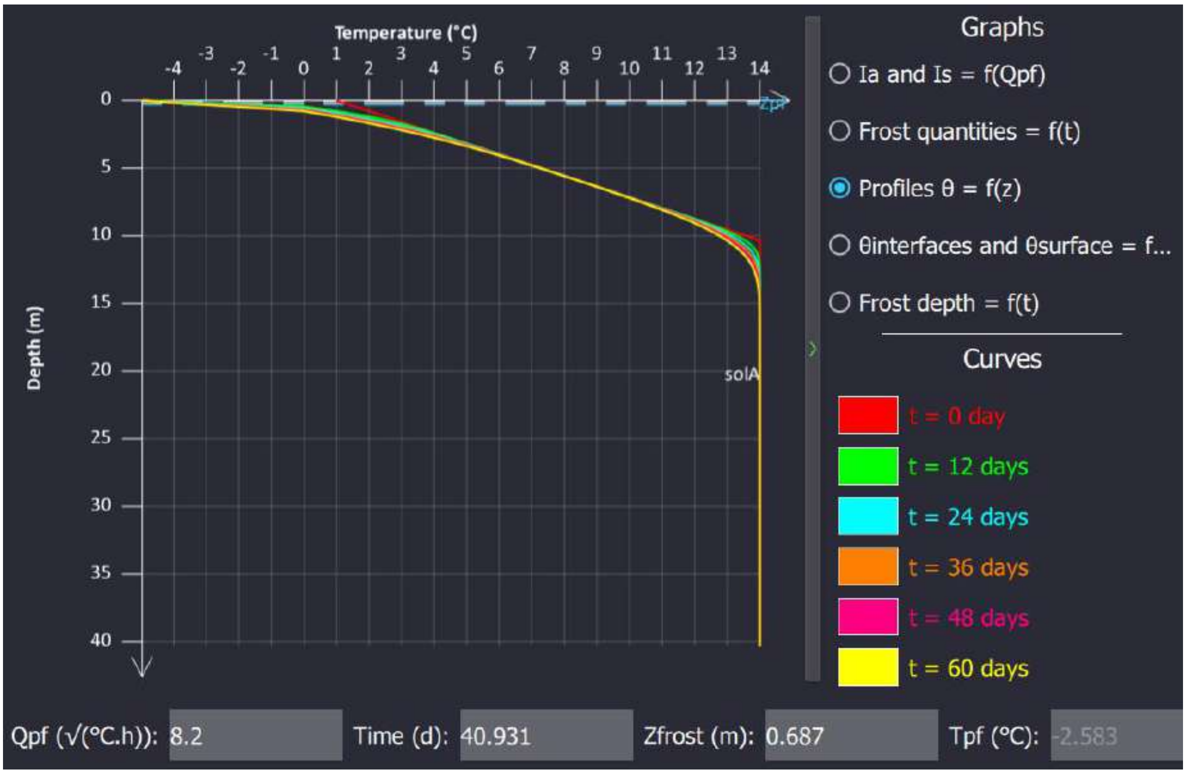


Figure 4-26: Vertical temperature profiles at different times

This graph displays the curve of the temperature corresponding to time t = 0 days, followed by a curve by 12-day intervals until reaching 60 days (length of observation).

➢ Graph of the temperature vs. time curves

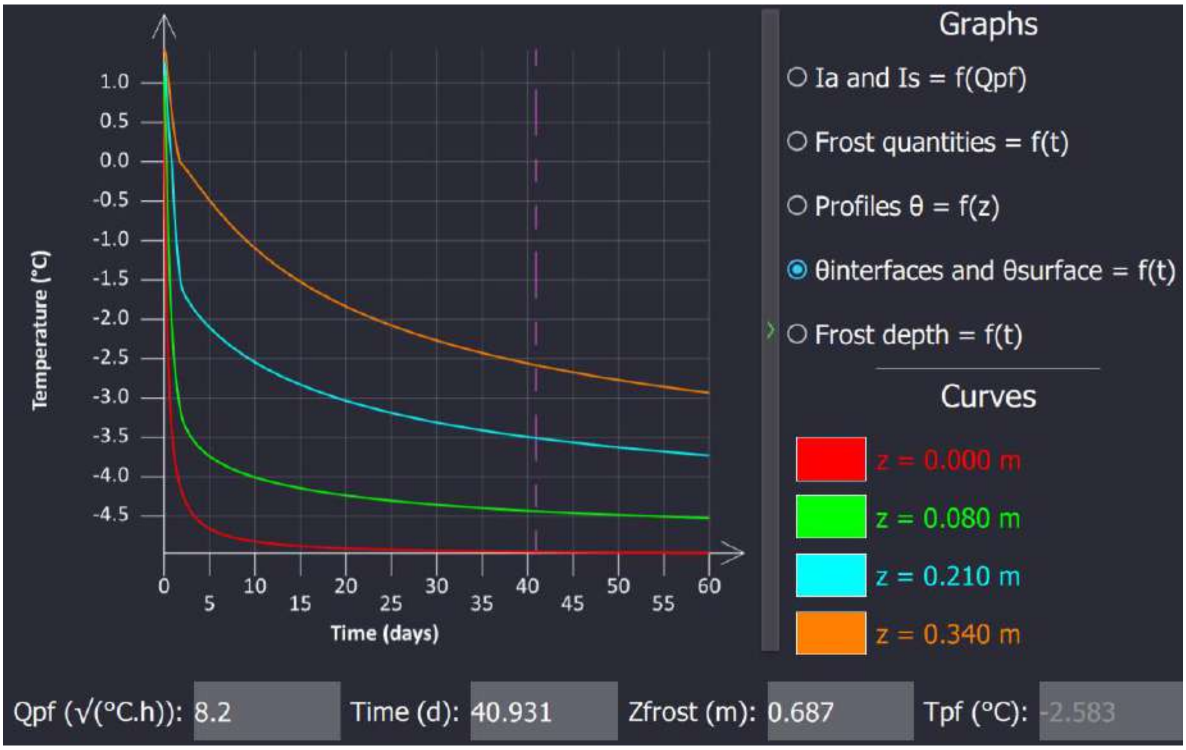


Figure 4-27: Temperature vs. time curves

A temperature curve is plotted for depths corresponding to the ground surface and at each layer interface. In the example of Figure 4-27:

- at the ground surface level: Z = 0.000 m – red curve
- at the 1st interface level: Z = 0.080 m – green curve
- at the level of potential subsequent interfaces: Z = 0.210 m – teal curve
- at the platform level: Z = 0.340 m – orange curve

The graph identifies, by means of the vertical dashed line, the value in days corresponding to the maximum admissible *Qpf* value, i.e. 40.931 days in the case of Figure 4-27.

➢ Graph of the frost depth vs. time curves

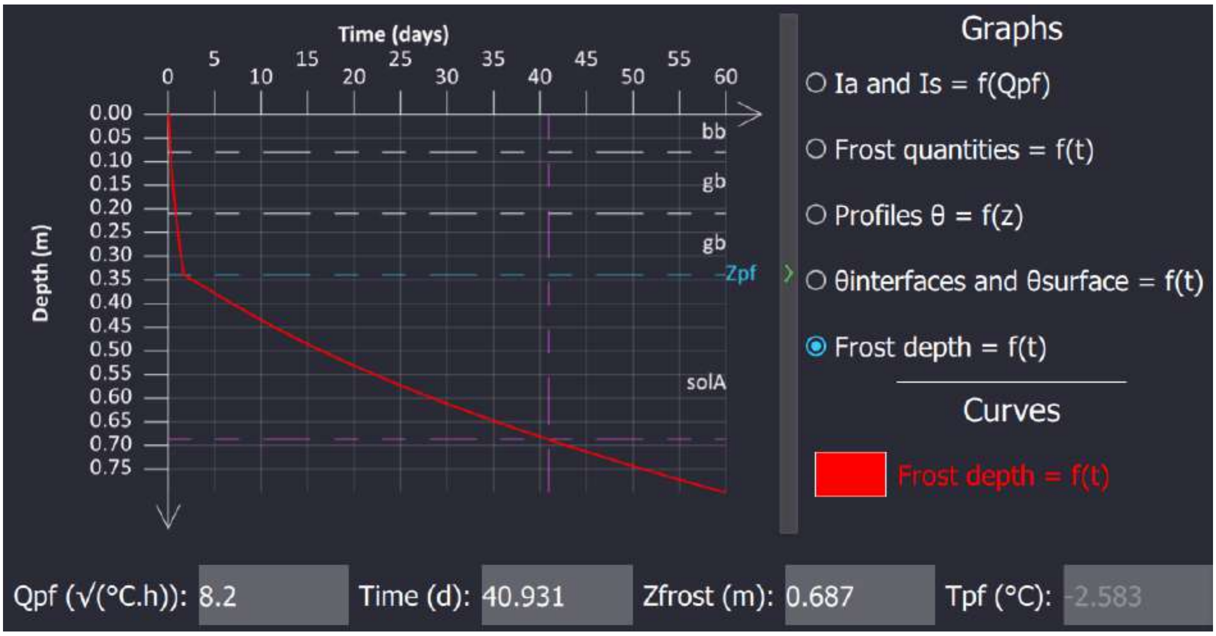


Figure 4-28: Frost depth vs. time curves

This graph serves to observe the evolution in the frost front propagation within the pavement layers over time.

The white horizontal dashed lines represent the depths at the layer interfaces of the pavement, while the blue dashed line depicts the depth at the top of the platform.

The purple dashed lines serve to identify the frost depth corresponding to the time when the frost quantity has reached the admissible value at the platform. These values, which can be observed on the graph, are transferred to the fields displayed below. In the illustration of Figure 4-28, the user can note that the frost penetrates to a depth of 0.687 m after a duration of 40.931 days.

- Frost report

The Project menu of the *Verification* tab contains a new option entitled *Frost report* (Figure 4-29), which allows generating a summary document.

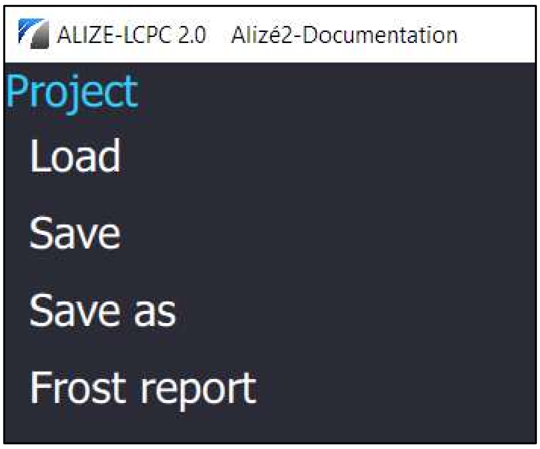


Figure 4-29: Access to the frost report via the Project menu

A window (Figure 4-30) makes it possible for the user to customize this report.

As such, the user can freely enter certain information to be displayed in the report, including:

- a unique project name, corresponding to the title assigned to this report as well as the author's name;
- a description of the study;
- a warning or observation regarding the study;
- a conclusion.

By clicking *Validate*, the report in pdf format is automatically generated and saved in the same folder as the project; it is given the name *calculationFrostNote_date_time*, with the date (recorded in "dd-mm-yyyy" format) and time ("hh-mm" format) correspond to the report generation event.

In the file name, it is important to only use those characters authorized by Windows.

In particular, the characters \ /: * ? " < > | are prohibited; also, it is strongly advised not to use spaces, accents and the % sign.

The report can only be generated if the project location has been defined locally or else via a network drive identified by a letter and address of the type Z:\....
The syntax "*name_server*\..." is to be avoided.

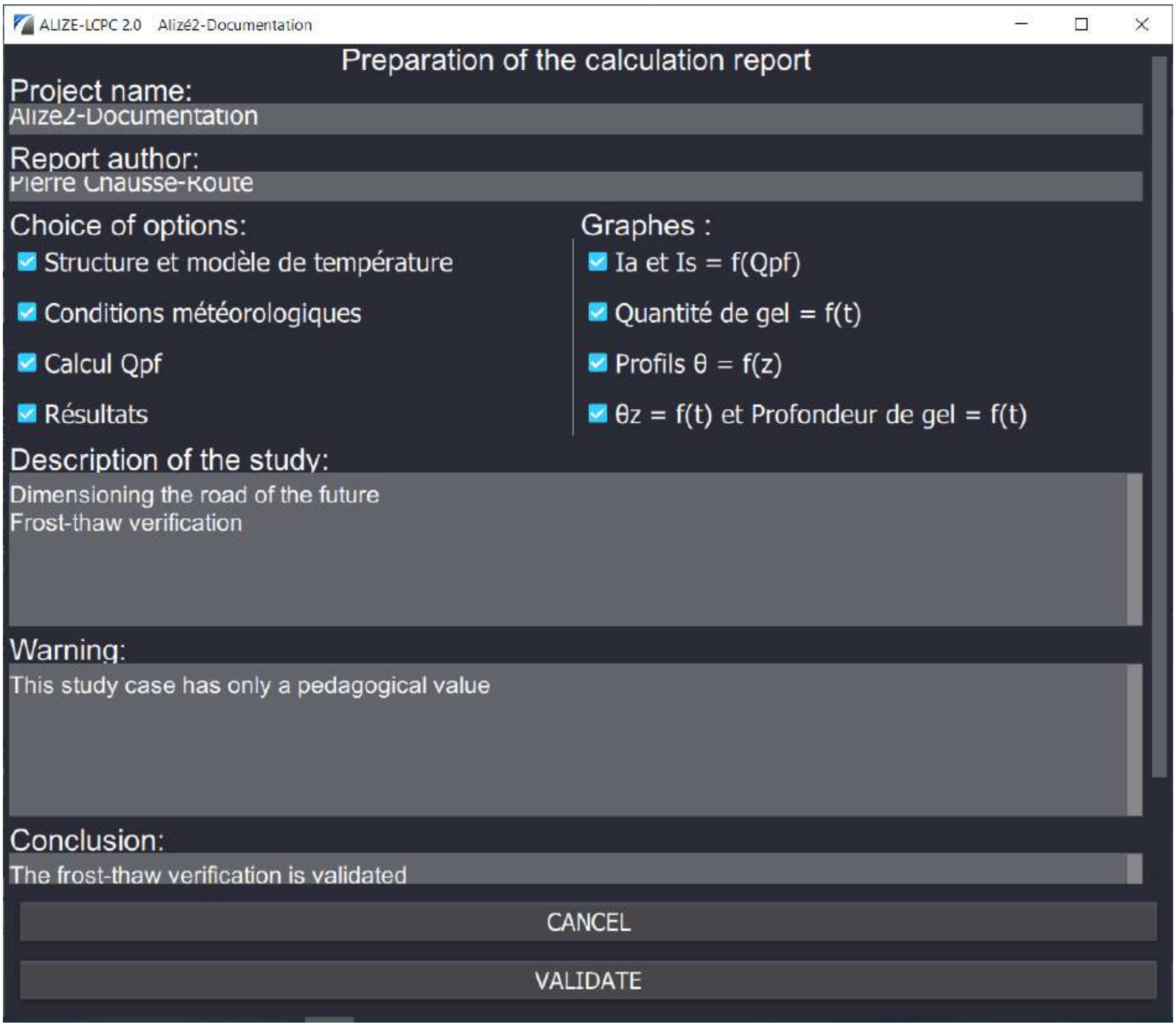


Figure 4-30: Settings for the frost report

The data stemming from the Structure tab and integrated into the report (Figure 4-31) are extracted from the data table of this tab, which have already been listed above (see 4.1.2 Structure).

The top of platform Zpf is also indicated.

1 Structure

Library	Type	Th (m)	ρ (kg/m3)	W (%)	λng (W/m.°C)	λg (W/m.°C)
NF P98-086 v2019	bb	0.08	2350	1	2	2.1
NF P98-086 v2019	gb	0.13	2350	1	1.9	1.9
NF P98-086 v2019	gb	0.13	2350	1	1.9	1.9
Sommet de la plateforme Zpf						
NF P98-086 v2019	solA	40	1300	32	1.1	1.8

Figure 4-31: Sample part of the frost report pertaining to the Structure tab

The temperature model employed is then provided (Figure 4-32):

2 Modèle de température

Temperatures: Lcpc-Setra model

Figure 4-32: Sample part of the frost report pertaining to the temperature model

The data stemming from the *Weather conditions* tab and incorporated into the report (*Figure 4-33*) are as follows:

- the parameters for calculating the admissible frost index *Ia*: Kcr, and the choice of location;
- the reference frost index value *Ir*, based on the type of winter and choice of weather station.

3 Meteorological conditions

Paramètres de calcul de l'indice de gel admissible Ia

Kcr: 0.7

Outside urban areas or urban areas with less than 100 000 inhabitants.

Choix de l'indice de gel de référence Ir

Hiver de type exceptionnel

Station: Ambérieu-en-Bugey

Ir: 270 °C.j

Figure 4-33: Sample part of the frost report pertaining to the Weather conditions tab

The data relative to the *Qpf* calculation and incorporated into the report are as follows:

- the choice of platform configuration, depending on the frost sensitivities (SGn, SGp, SGt) of the materials (*Figure 4-13*);
- the platform layer characteristics, i.e. the height of the upper platform layer and all coefficients necessary for the calculation of *Qg* and *Qng* (*Figure 4-34*);
- the pavement thickness that allows conducting the calculation of *Qm (Figure 4-35)*;
- the result *Qpf* of the sum of values *Qg*, *Qng* and *Qm (Figure 4-36)*.

4 Qpf computation

SGn	**SGt**	**Unit**
Hn = 0.5		m
An = 14 (C1/A1)		(°C.j)^(1/2).m^-1
	p = 0.6	mm/(°C.h)^(1/2)

Thick pavement, e = 0.07 m

Qm = 0.7 (°C.j)^(1/2)

Qng	**Qg**	**Qm**
5.83333	1.66667	0.7

Qpf = Qg + Qng + Qm = 8.2 (°C.j)^(1/2)

Figure 4-34: Sample part of the frost report pertaining to the Qng and Qg calculations

Figure 4-35: Sample part of the frost report pertaining to the Qm calculation

Figure 4-36: Sample part of the frost report pertaining to the Qpf calculation

The *Results* part (*Figure 4-37*) of the frost report provides:

- the characteristics calculated: the value of Qpf, the time and associated frost depth Zfrost, plus the admissible atmospheric frost index value *Ia*;
- a reminder of the reference chosen to draw a comparison with the calculation;
- a summary conclusion on the validity or invalidity of the structure with respect to frost.

5 Results

Caractéristiques calculées :
- Quantité de gel admissible au niveau de la plateforme : Qpf = 8.2 (°C.j)^(1/2)
- Temps = 40.931 j
- Profondeur de gel : Zgel = 0.687 m
- Indice de gel atmosphérique admissible : Ia = 289.738 °C.j

Référence choisie :
- Valeur de l'indice de gel de référence Ir = 270 °C.j
- Station météorologique correspondante : Ambérieu-en-Bugey

Pour que la vérification au gel/dégel soit satisfaite, il faut que la valeur de l'indice de gel atmosphérique admissible Ia soit supérieure ou égale à celle de l'indice de gel Ir choisie.

Ia = 289.738 °C.j >= Ir = 270 °C.j

Vérification satisfaite.
La capacité de la structure à résister à un cycle de gel/dégel est vérifiée dans la limite des hypothèses émises.

Figure 4-37: Sample part of the frost report pertaining to these results

The Graphs part displays the various graphs selected. *Figure 4-38* shows one such graph, but keep in mind that they are all presented in much the same format.

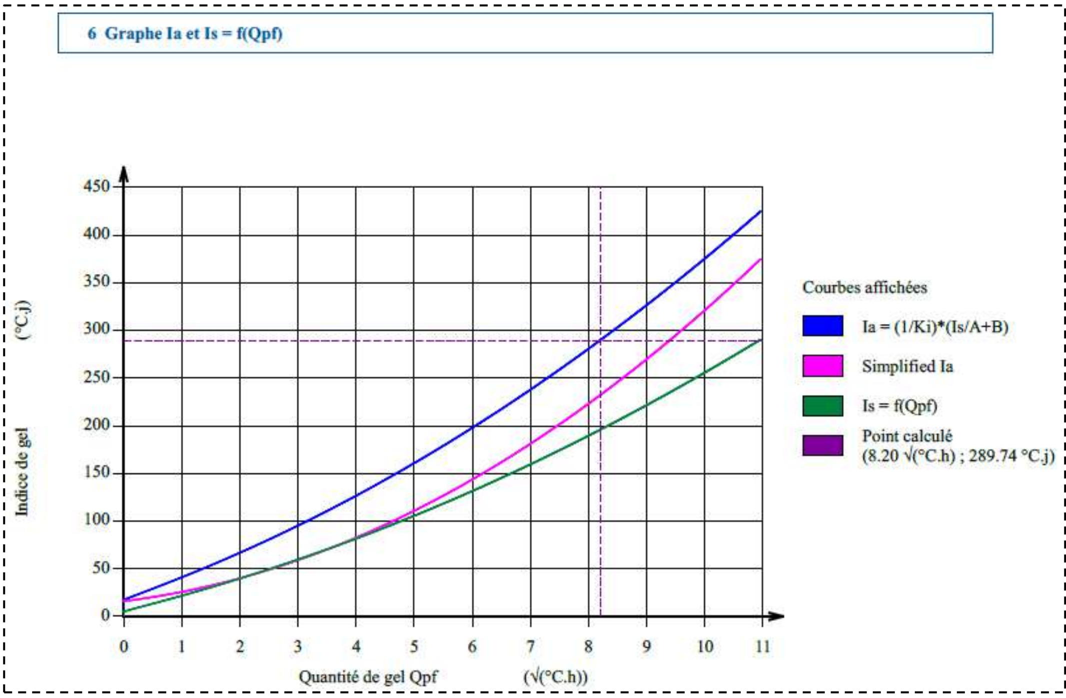


Figure 4-38: Sample graph

Lastly, the *Conclusion* part (Figure 4-39) replicates precisely and exclusively the contents of the field with the same name entered by the user in the configuration window prior to generating the frost report:

11 Conclusion

The frost-thaw verification is validated

Figure 4-39: Sample frost report conclusion

5 Bibliography

[1] Commission de normalisation, NF P 98-086. Dimensionnement structurel des chaussées routières -- Applications aux chaussées neuves., AFNOR, 2019.

[2] D. M. Burmister, "The theory of stresses and displacements in layered systems and applications of the design of airport run ways," *Proceedings of the Highway Research Board,* no. 23, pp. 126-148, 1943.

[3] LCPC, SETRA, Conception et dimensionnement des structures de chaussée. Guide Technique., 1994.

Appendices

A1 Loading of a personal materials library

A1.1 Introduction

The software Alizé2® allow the user to load a previously defined materials library in a .csv formatted file.

This file may be uploaded from Version 2.0.6 of the Alizé2® software.

A1.2 Loading of the library

To upload a library, the user opens the dedicated materials libraries window. This step entails accessing the Structure tab of the *Standard road design* module, found in the Mechanical part. In this tab's side toolbar, the user is to click on the *Materials library* button (Figure A4 - 1).

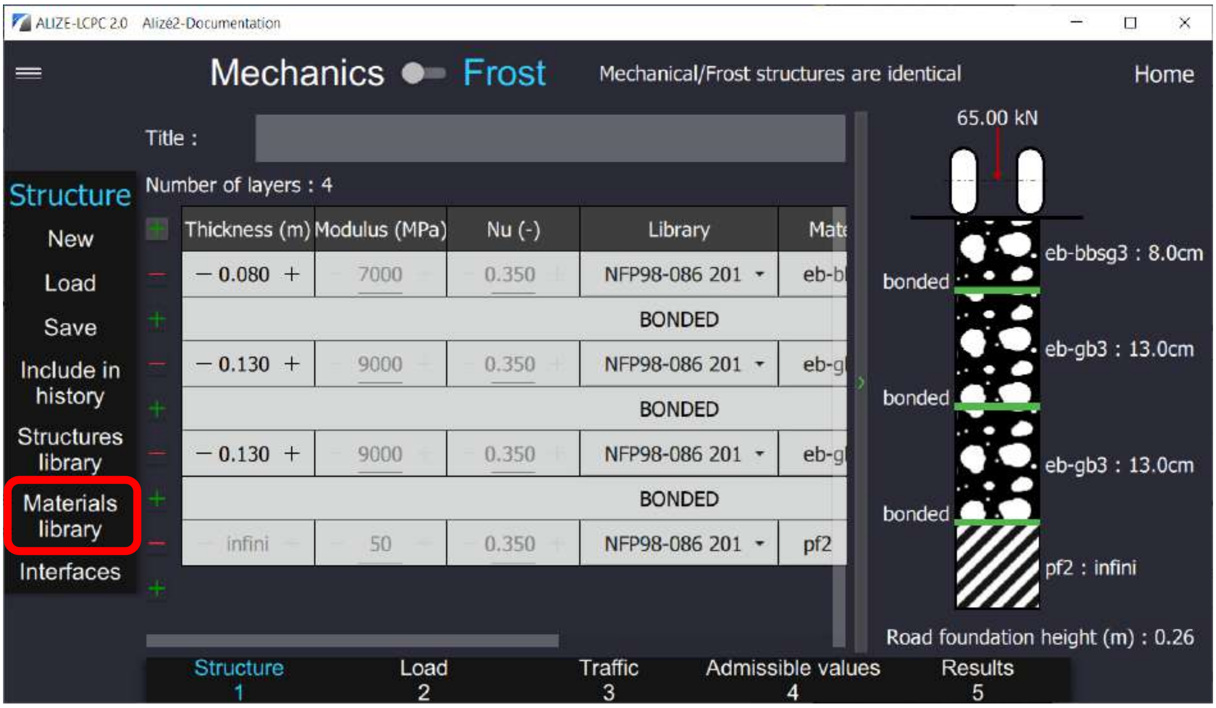


Figure A4 - 1: Opening of the window to visualize the materials libraries

A new window will open. At this point, the user can click the *Load* button (Figure A4 - 2) and then define the path leading to the designated .csv-formatted file.

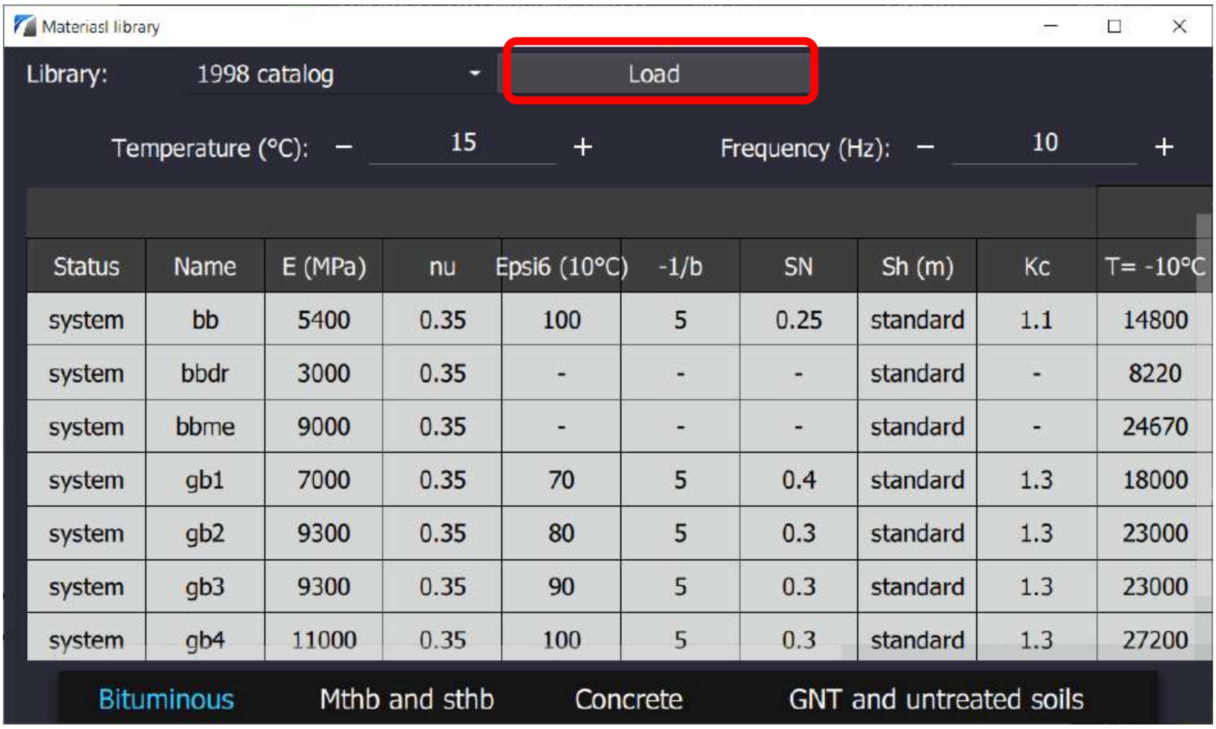


Figure A4 - 2: Loading of a user library

Next, once the library has been uploaded, the user can specify a structure using this materials selection (Figure A4 - 3).

Figure A4 - 3: Choice of the user library (User Library 1)

A1.3 Presentation of the file

This file comprises two types of rows:

- rows beginning by the symbol "#" not read by Alizé2® and serving to comment, describe, etc.;
- rows beginning by the symbol "!" serving to define the materials.

Each row of material is composed of 26 columns:

- name of the material, as chosen by the user;
- type of material, which must be: bitum (bituminous), beton (concrete), trait (materials treated with hydraulic binder - MTHB), gntSo (untreated gravel or untreated soil) or soTrait (soil treated with hydraulic binder - STHB);
- name of the library, as chosen by the user;
- E: Young's modulus;
- v: Poisson's ratio;
- Sigma6: average stress magnitude value leading to a bending fatigue life cycle of 10^6 cycles, with a 50% probability on a material aged at least 360 days (NF P98-233-1);
- Epsi6: average strain magnitude value leading to a classical failure of the sample under 10^6 cycles with a 50% probability (50% reduction in the initial force);
- 1/b, with b being the fatigue law slope of the material determined based on the same test by means of a bi-logarithmic linearization between 10^5 and 10^7 cycles ($-1 < b < 0$);
- b, for calculating $\varepsilon_{z\,adm}$;
- at a light traffic level for calculating $\varepsilon_{z\,adm}$;
- at a heavy traffic level for calculating $\varepsilon_{z\,adm}$;
- Sn: standard deviation on the decimal logarithm of the number of cycles leading to failure by fatigue;
- Sh: standard deviation on the total thickness of the layers of base course materials implemented;
- Kc: coefficient of calibration;
- Kd: coefficient of discontinuity;
- E(-10°C): Young's modulus at -10°C, 10 Hz;
- E(0°C): Young's modulus at 0°C, 10 Hz;
- E(10°C): Young's modulus at 10°C, 10 Hz;
- E(20°C): Young's modulus at 20°C, 10 Hz;
- E(30°C): Young's modulus at 30°C, 10 Hz;
- E(40°C): Young's modulus at 40°C, 10 Hz;
- description of the material;
- Ro: dry mass density;
- W: mass water content;
- Ldang: thermal conductivity factor in the unfrozen state;
- Ldag: thermal conductivity factor in the frozen state.

A1.4 Defining a material

Depending on the type of material, the columns to be filled in are indicated by the symbol "X" in the following table. The unnecessary columns may remain empty (without any values).

	Bituminous	**Concrete**	**MTHB**	**GNT and untreated soils**	**STHB**
Name of material	X	X	X	X	X
Type of material	bitum	beton	trait	gntSo	soTrait
Name of library	X	X	X	X	X
E (MPa)		X	X	X	X
v (-)	X	X	X	X	X
Sigma6 (MPa)		X	X		X
Epsi6 (µ)	X				
1/b	X	X	X		X
b				X	
with light traffic				X	
with heavy traffic				X	
Sn	X	X	X		X
Sh	(3)	(4)	X		X
Kc	X	X	X		X
Kd			X		X
E(-10°C) (MPa)	X				
E(0°C) (MPa)	X				
E(10°C) (MPa)	X				
E(20°C) (MPa)	X				
E(30°C) (MPa)	X				
E(40°C) (MPa)	X				
Description of the material	X(1)	X(1)	X(1)	X(1)	X(1)
Ro (kg/m^3)	X(2)	X(2)	X(2)	X(2)	X(2)
W (%)	X(2)	X(2)	X(2)	X(2)	X(2)
Ldang (W/m.°C)	X(2)	X(2)	X(2)	X(2)	X(2)
Ldag (W/m.°C)	X(2)	X(2)	X(2)	X(2)	X(2)

(1) Optional.

(2) If no value has been entered, a zero value will be selected. Entry required if frost verification is anticipated.

(3) In the case of a bituminous material, the value of Sh is determined by the software by applying the calculation rule set forth in the standard (NF P98-086, Section 3.1.1).

(4) In the case of concrete, the value of Sh is chosen by the user during the design depending on both the implementation hardware, as defined in Standard NF P98-170, and the position of the layer in the pavement (NF P98-086, Section 4.1.2).

Let's note that, with the exception of the moduli of elasticity at the different temperatures of bituminous materials, the parameters of "user" materials employed in a studied structure may be modified (without the modifications being saved in the .csv file).

A1.5 Example of file without any formatting

#;;;;;;;;;;;;;;;;;;;;;;;;;;

#;;;;;;;;;;;;;;;;;;;;;;;;;;

#; Name mat; Type; Name biblio; E; nu; sigma6; epsi6; 1/b; b; With light traffic; With heavy traffic; Sn; "Sh"; Kc; Kd; E(-10°C); E(0°C); E(10°C); E(20°C); E(30°C); E(40°C); Description; ro; w; ldang; ldag

!;concrete 1;concrete;User Library 1;35000;0.25;2.15;;16;;;;1;;1.5;;;;;;;;Concrete test;2300;3;1.7;1.9

!;concrete 2;concrete;User Library 1;35000;0.25;2.15;;16;;;;1;;1.5;;;;;;;;Concrete test;2300;3;1.7;1.9

!;concrete 3;concrete;User Library 1;35000;0.25;2.15;;16;;;;1;;1.5;;;;;;;;Concrete test;2300;3;1.7;1.9

!;bitum 1;bitum;User Library 1;;0.35;;100;5;;;;0.25;;1.1;;16000;13500;9310;4690;1800;1000;Bitum test;2350;1;2;2.1

!;mtlh 1;treat;User Library 1;3700;0.25;0.175;;10;;;;0.8;0.025;1.5;1;;;;;;;MTLH test;1900;7;1.1;1.3

!;gnt 1;gntSo;User Library 1;200;0.35;;;;-0.222;16000;12000;;;;;;;;;;;Gnt test;2200;4;1.8;2

!;stlh1;soTreat;User Library 1;3700;0.25;0.175;;11;;;;1;0.05;1.4;1;;;;;;;STLH test;;7;1.1;1.3

!;stlh2;soTreat;User Library 1;;0.25;0.175;;11;;;;1;0.05;1.4;1;;;;;;;STLH test;1900;7;1.1;1.3

A1.6 Example of a file within a spreadsheet

#	Nom mat	Type	Nom biblio	E	nu	sigma6	epsi6	1/b	b	A faible trafic	A fort trafic	Sn	Sh	Kc	Kd	E(-10°C)	E(0°C)	E(10°C)	E(20°C)	E(30°C)	E(40°C)	Description	ro	w	ldang	ldag
!	beton 1	beton	User Library 1	35000	0.25	2.15		16				1		1.5								Beton test	2300	3	1.7	1.9
!	beton 2	beton	User Library 1	35000	0.25	2.15		16				1		1.5								Beton test	2300	3	1.7	1.9
!	beton 3	beton	User Library 1	35000	0.25	2.15		16				1		1.5								Beton test	2300	3	1.7	1.9
!	bitum 1	bitum	User Library 1		0.35		100	5				0.25		1.1		16000	13500	9310	4690	1800	1000	Bitum test	2350	1	2	2.1
!	mtlh 1	trait	User Library 2	3700	0.25	0.175		10				0.8	0.025	1.5	1							MTLH test	1900	7	1.1	1.3
!	gnt 1	gntSo	User Library 1	200	0.35				-0.222	16000	12000											Gnt test	2200	4	1.8	2
!	stlh1	soTrait	User Library 1	3700	0.25	0.175		11				1	0.05	1.4	1							STLH test		7	1.1	1.3
!	stlh2	soTrait	User Library 1		0.25	0.175		11				1	0.05	1.4	1							STLH test	1900	7	1.1	1.3

A2 Versions

A2.1 Software

Version number	Sortie	Corrections / Upgrades
2.0.0 to 2.0.3		Road design module with frost verification
2.0.4	June 2019	First commercial version
2.0.5	March 2020	**Corrections:** - Problem with temperature and frequency display when transitioning from the frost module to the mechanical module; - Admissible values: number of significant digits for the displayed admissible stress; - Concrete: modification of the 1/Kd parameter; - Recording of the title of the structure; - Standardization of titles for both the mechanical and frost parts; - Saving of the Ks coefficient when saving the current project; - Zero geometric expansion; - Special value for Ks; - Number of characters used for the study description; - Platform thickness in the calculation note changed to 0.1 m. **Upgrades:** - Update of the "AAC", "Risk" and "Interface" guides to comply with the new 2019 Standard NF P98-086 [1]; - Addition of a "Unique pavement cross-section" guide, in accordance with the 2019 Standard NF P98-086 [1]; - Importation of a "user" materials library from a .csv-formatted file in compliance with a given formatting; - Specification of the base course in the "Structure" tab, followed by an automatic update of the base course thickness for the calculation of admissible values; - Choice of material in the "Structure" tab: compilation by type; - "Structure" and "Results" tabs: addition of scroll bars.
2.0.6	Oct 2020	Specification of the user library Various modifications and upgrades
	2021	Aeronautical design module

A2.2 Documentation

Version number	Release	Corrections / Upgrades
2.0.1	August 2020	Road design module
2.0.2	November 2020	Appendix A4 – User library
2.1	May 2021	Frost verification

List of abbreviations and acronyms

GNT: Untreated gravel

IFSTTAR: French Institute of Science and Technology for Transport, Development and Networks

JS: Javascript

LCPC: former Public Works Research Laboratory

MTHB: Materials Treated with Hydraulic Binders

QML: Qt Markup Language

Setra: Transport and Road Research Laboratory (a French technical unit with nationwide jurisdiction within the Ministry of Ecological and Solidarity Transition – MTES)

SNT: Untreated Soils

STAC: Civil Aviation Technical Center

STHB: Soils Treated with Hydraulic Binders

VB6: Visual Basic, Version 6

VRNS: Non-Structural Network Links

VRS: Structural Network Links

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