



TcpTUNNEL

6

Reference Manual

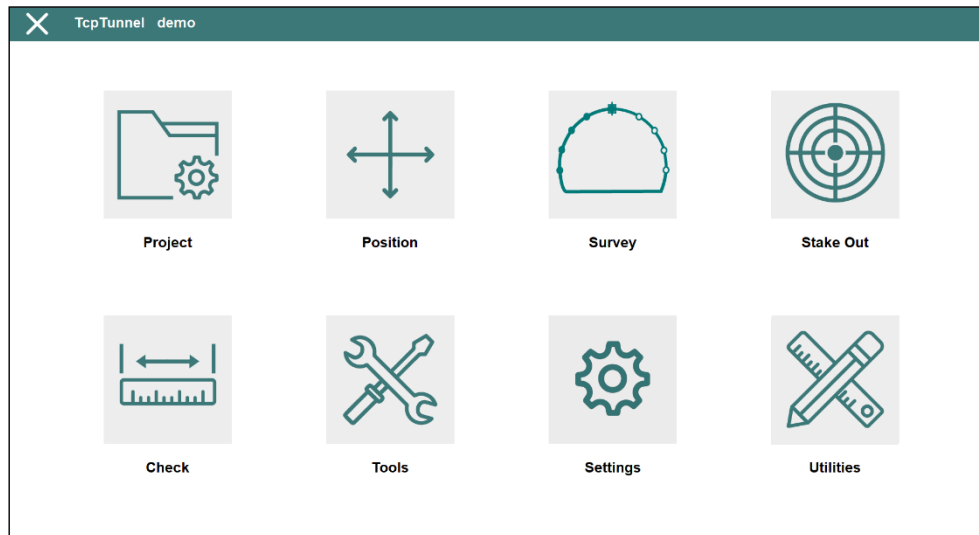
1. Table of Contents



1. TABLE OF CONTENTS	2
1. FEATURES AND FUNCTIONALITY	4
1.1. UNITS	5
1.2. COORDINATE SELECTION	6
1.3. THEORETICAL POINTS OF THE TUNNEL TEMPLATE	6
1.4. APPLICATION STARTUP	11
2. PROJECTS	11
2.1. PROPERTIES	12
2.2. COMPONENTS	13
2.3. DRAW	14
2.4. SELECT	14
2.5. NEW	14
2.6. DELETE	14
2.7. FILE MANAGEMENT	14
3. FILE MANAGEMENT	16
3.1. COMMON FUNCTIONS	16
3.2. POINTS	18
3.3. CONTROL POINTS	22
3.4. HORIZONTAL ALIGNMENTS	26
3.5. VERTICAL ALIGNMENTS	29
3.6. SUPERELEVATIONS	32
3.7. TUNNEL TEMPLATES	34
3.8. RESULTS	40
3.9. RAW DATA	42
4. POSITIONING	45
4.1. LAST POSITION	45
4.2. ANGULAR	45
4.3. BY COORDINATES	46
4.4. RESECTION	47
5. SURVEYING	58
5.1. CROSS-SECTION	58
5.2. POINTS	61
5.3. GRID	62
5.4. SCAN	63
6. STAKE OUT	65
6.1. FRONT	65
6.2. CROSS SECTIONS	68
6.3. ROCK BOLTS	71
6.4. POINTS	72
6.5. ROAD SURFACE	75
7. CHECKING	77
7.1. CROSS SECTIONS	77


7.2.	POINTS	80
7.3.	CROSS SECTIONS DRAWING	80
8.	SETTINGS	83
8.1.	OPTIONS	83
8.2.	UNITS OF MEASUREMENT	84
8.3.	SURVEY	84
8.4.	TOLERANCES	85
8.5.	INSTRUMENT	86
8.6.	COMMUNICATIONS	87
8.7.	CODES DATABASE	88
9.	TOOLS	90
9.1.	POINT CALCULATION	90
9.2.	POINT ANALYSIS	91
9.3.	DISTANCE BETWEEN POINTS	92
9.4.	AREA BETWEEN POINTS	92
9.5.	LINE INTERSECTION	93
9.6.	LINE AND CIRCLE INTERSECTION	94
9.7.	CIRCLE AND CIRCLE INTERSECTION	94
9.8.	POLAR TO RECTANGULAR COORDINATES	94
10.	UTILITIES	96
10.1.	MEASUREMENT	96
10.2.	SYSTEM INFORMATION	97
10.3.	LICENSE	97
10.4.	ABOUT	97
11.	ABBREVIATIONS	99


1. Features and Functionality

TcpTunnel is an application based on dialog boxes that are presented on a main menu comprised of a series of buttons that enable one to access the program's different options.



To exit a dialog box, either the accept () or cancel () buttons should be clicked. These appear on the upper side of the screen. The cancel button allows one to exit the dialog box without accepting any changes or without taking account of any calculations that may have been made.

Most of the dialogs show, on the title bar, the menu button . This button allows user to run several options.

Help button, , is also shown in some screens to open the documentation about the current function.

TcpTunnel works with projects, which are made up of different ASCII files. For users having **TcpTunnel CAD** application, the projects are totally compatible, although, simple projects can be created directly in TcpTunnel. Both programs usually work together and the general workflow is as follow:

	<i>TcpTunnel CAD</i>	<i>TcpTunnel TS</i>
1	Project definition Tunnel template creation Tunnel template assignments	
		2 Survey cross sections Check cross sections Stake out front / cross sections
3	Cross section calculations Cross section drawing Report generation Cross section comparison Tunnel 3D model	


1.1. Units

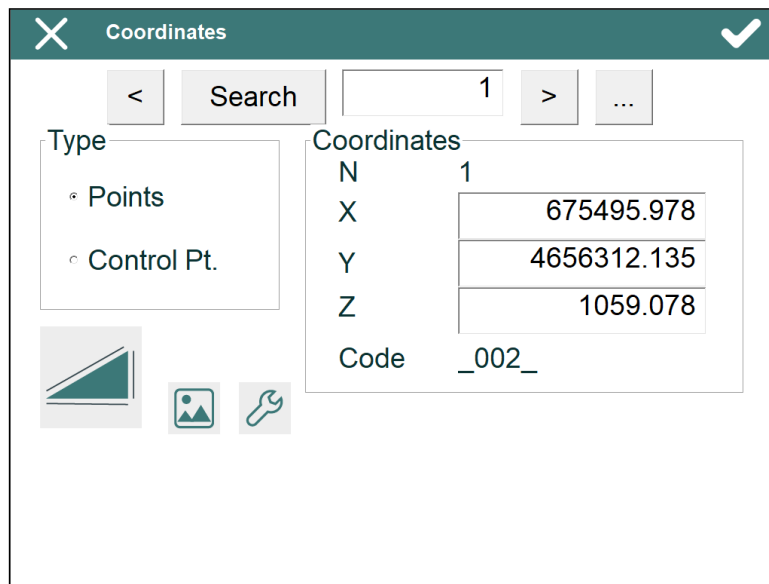
The units of measurement of the application's data are as follows:


Data	Units
Coordinates	Meters
Heights	Meters
Distances	Meters
Surface areas	Square meters
Perimeters	Meters
Azimuths	Gons/decimal degrees. 0° North
Tolerances	Meters
Lengths	Meters
Stake Heights	Meters
Prism Constant	Milimeters
Stations (Chainages)	Meters
Station Intervals	Meters
Tolerances	Meters
Superelevations	Percentage
Angle Increments	Gons/decimal degrees
Length Increments	Meters
Height Increments	Meters

The angular units can be configured as gons (default) or decimal degrees.

1.2. Coordinate Selection

In the options of the program where necessary to indicate the coordinates of a point will be accessed through the button , to the next screen:



< >: These buttons allow one to move through the different points of the file selected in the **Type** section. If one pushes the  button, the list of the selected type is displayed.

Search: This button allows one to go directly to the point indicated in the box next to it.



This button allows one to make a total station observation.



This button allows one to graphically select a point from the station or point file.



Allows one to configure some features of the total station.

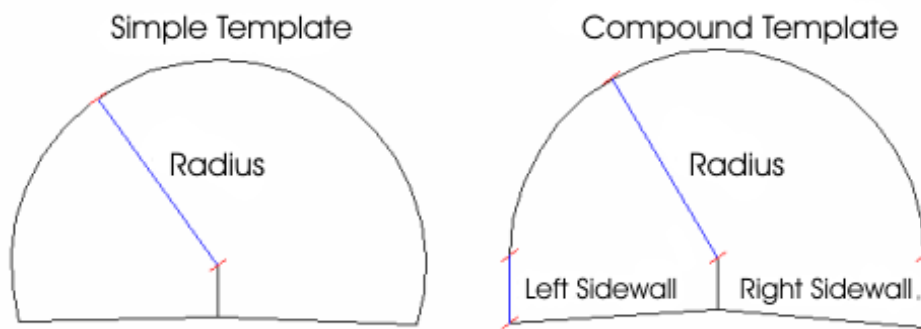
1.3. Theoretical Points of the Tunnel Template

The application allows one to work with 3 kinds of cross-sections:

Simple template: A circular template defined from a radius.

Composite template: Defined from a radius and sidewalls.

Complex template: Defined by a succession of curved and straight sections.



Of these, only the first two can be defined in the field data recorder itself. Complex cross-sections have to be created with the TcpTunnel CAD program. All cross-sections created in this module will be treated by the application as if they were complex, even if they are simple or composite cross-sections.

Said cross-sections can be included or not in the road surface or inverted arch zones. They will be considered as **Open** if they do not include them and **Closed** otherwise. The kind of cross-section one wishes to create has to be indicated in the field data recorder, while in CAD it is done automatically depending on whether the polyline created is open or closed.

The cross-section center and three distances marking where the alignment is marked on the ground plan, the vertical alignment and the superelevations will be requested in all cases. One must additionally specify how the cross-section varies as a function of the superelevations (see **Edit** section).

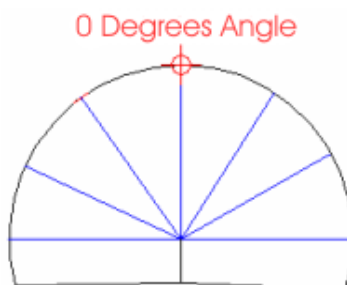
The vertical alignment and superelevation application point should be within the tunnel cross-section.

All the data referring to cross sections requested and shown in the application are understood to be in the forward direction of stations on the project's alignment.

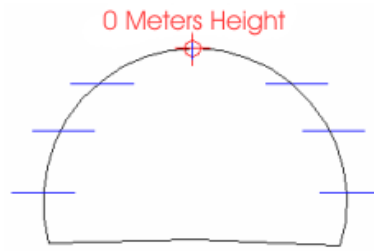
The survey and set out profiles, set out front and position options allow one to divide the section into specific theoretical points starting off from the keystone up to the values indicated to the left and the right of the keystone. Exclusion zones can be defined.

There are three different ways.

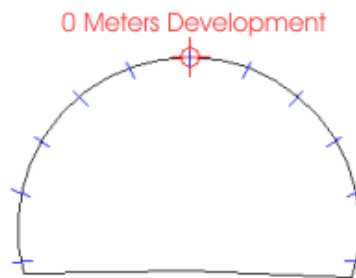
Angle Increment:



Z (Height) Increment:



Length Increment:



The screen below shows the data that has to be entered to divide the cross-section.

×

Cross section Points

✓

Method

Length (meters)

Interval

1.000

Initial Value

<

Final Value

<

Include Keystone

Unique Points

Include Road Surface

Exclusions

Method: Shows the three methods indicated above: *Angle (degrees)*, *Height (meters)* and *Length (meters)*. In the case of angles, gons or decimal degrees will be displayed, depending on the option selected in **Settings** > [Units of Measurement](#).

Interval: A value that is always positive by which it increases or decrease starting off from the keystone to calculate theoretical points. For instance:

Angle: 20 degrees. Points calculated are: 0° (keystone), -20, -40, ..., 20, 40, ...

Height: 1 meter. The keystone is calculated as are the points at 1, 2, 3, etc. meters below it to the left and to the right.

Length: 2 meters. The keystone is calculated as are the points at 2, 4, 6, etc. meters of development to the left and to the right.

This option may be activated or deactivated. This allows one to only set out the keystone, which is always calculated, or unique points.

Include Keystone: Allows one to activate or deactivate the keystone point.

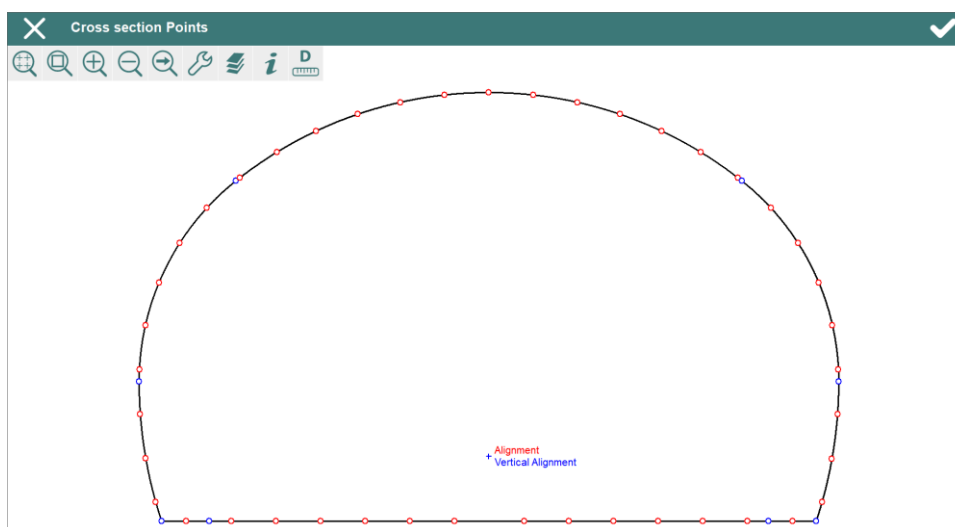
Unique Points: If this option is enabled, the cross-section's unique points are added.

Include Road Surface: The road surface cross-section is made up of two segments that have the vertical alignment and superelevation application point as the initial point and the intersection with the left-hand (left-hand segment) and right-hand side (right-hand segment) of the tunnel cross-section as the final point. If there is a superelevations file in the project, these segments will be superelevated as per the superelevation of the corresponding station observed or indicated.

If this option is enabled, the cross-section limits will be marked by the final points of the segments mentioned above.



Shows template graphic containing the theoretical points calculated.



The blue points indicate the cross-section's unique points, and the red points indicate the points calculated from the keystone on the basis of the increment indicated.

Regardless of the type of choice, **Interval**, **Unique Points** or both, one can exclude points from among all those calculated by any of the three methods. There are two ways of doing this, which can be used together:

1.- Establish the values of the **Initial Value** and **Final Value** boxes, so that only the points within the specified interval will be valid. The criteria for defining this interval are:

- Both values can be positive or negative.
- The initial value must always be smaller than the final value.

- The negative values indicate the left-hand side of the keystone and the positive values indicate its right-hand side.
- The range is created clockwise.

The > buttons alongside the **Initial** and **Final** boxes allow one to set a value by a reading.

Examples:

Angle: **Initial Value -100.0000 Final Value 125.0000**

Points included between 100 degrees to the left of the keystone and 125 to its right.

Initial Value -100.0000 Final Value -20.0000

Points included between 100 degrees to the left of the keystone.

Height: **Initial Value -10.0000 Final Value 5.0000**

Points included between 10 meters below the keystone on the left-hand side and 5 meters below the keystone on the right-hand side.

Initial Value 4.0000 Final Value 12.0000

Points included between 4 and 12 meters below the keystone on the right-hand side.

Length: **Initial Value -10,000 Final Value 12.5000**

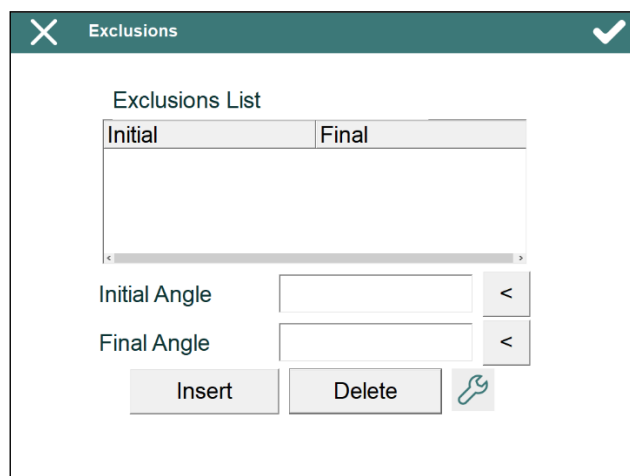
Points included between a length of 10 meters along the left-hand side of the keystone and 12.5 meters on the right-hand side.

Initial Value -9.0000 Final Value -5.0000

Points included between a length of 9 and 5 meters along the left-hand side of the keystone.

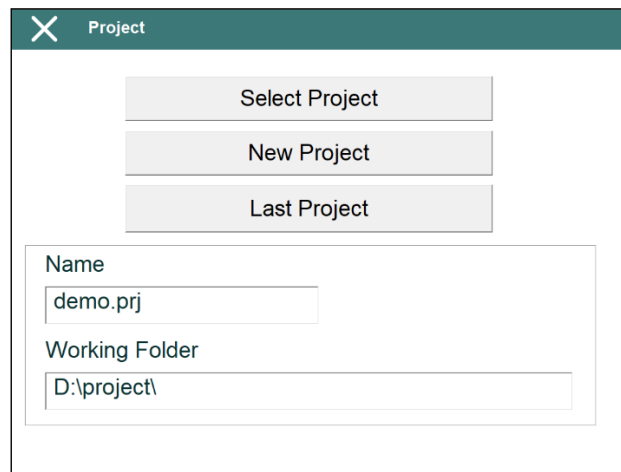
2.- Establish exclusion zones, discarding the points included between the established intervals. The criteria for creating these zones are the same as in the previous section, with the difference that one can only establish angle values.

The  buttons alongside the **Initial Angle** and **Final Angle** boxes allow one to set a value by measuring.



1.4. Application Startup

To start the application, the user needs to create a new job or select an existing one, for this, after the home screen, the program shows the following project window:



Last Project: This option selects the project worked in the last session. In this case, the application shows the **Name** and the **Working Folder**. When the application is initiated for the first time or when the program's initial configuration is restored, it appears as deactivated.

Select Project: Allows one to select a previously created project.

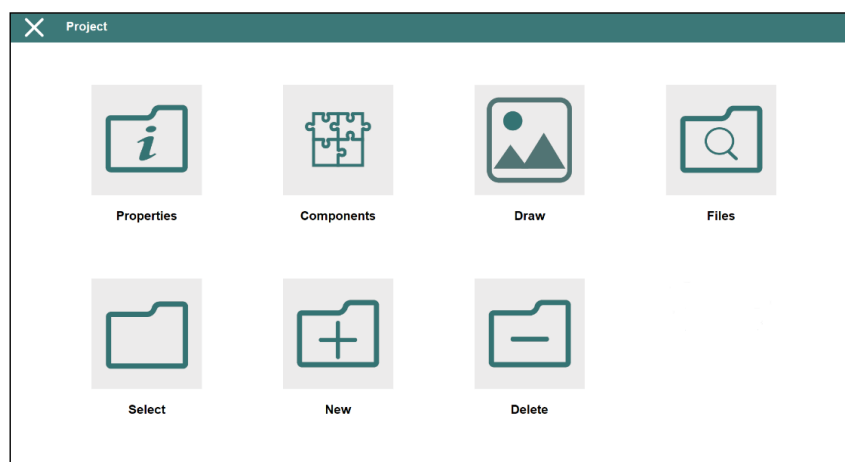
New Project: Allows one to create an empty project.

Once the project to be worked on is selected, the application's main menu is shown. On the title bar appears the application's name and the project's name.

2. Projects

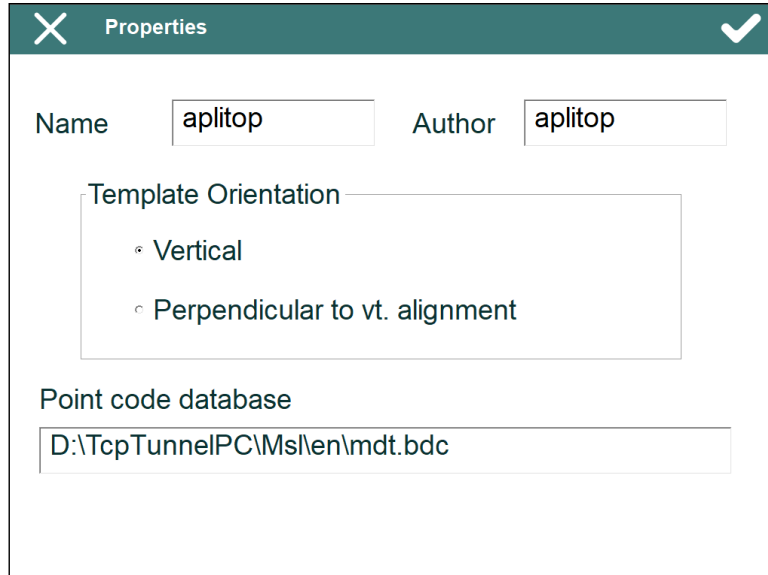
In order to avoid having to remember each of the files making up a project, this type of file has been created to store the links to each of the project's essential components.

The following options are available to manage this kind of file:



2.1. Properties

Allows one to choose how tunnel templates will be created along horizontal alignment, **Vertical** or **Perpendicular to vertical alignment**. This one must be used when vertical alignment slopes are great.



Properties

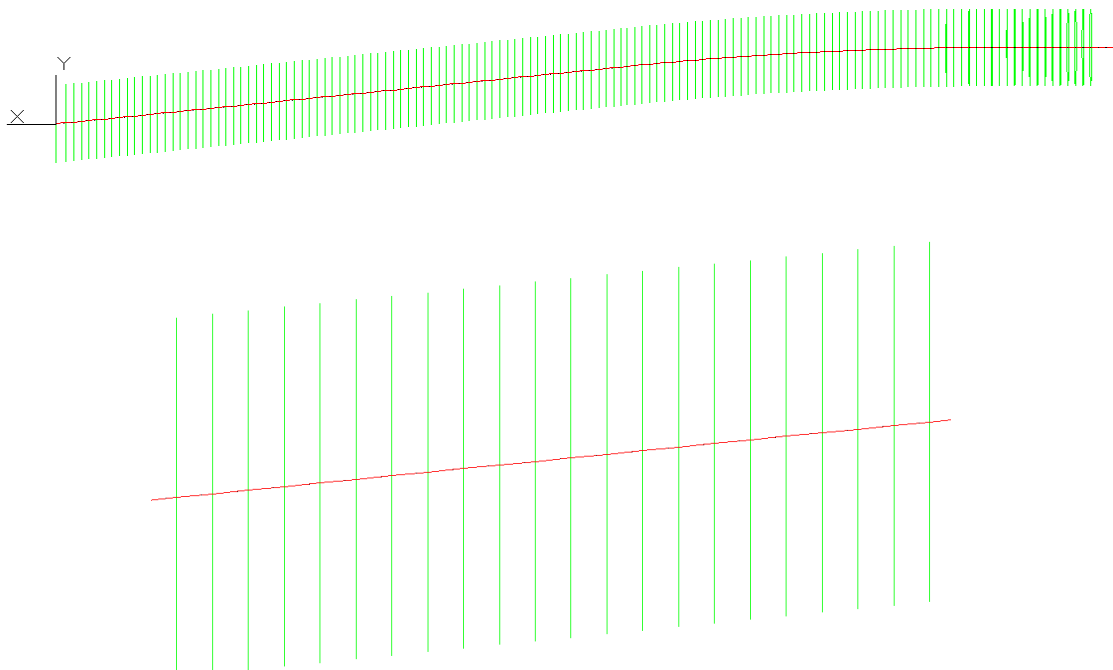
Name Author

Template Orientation

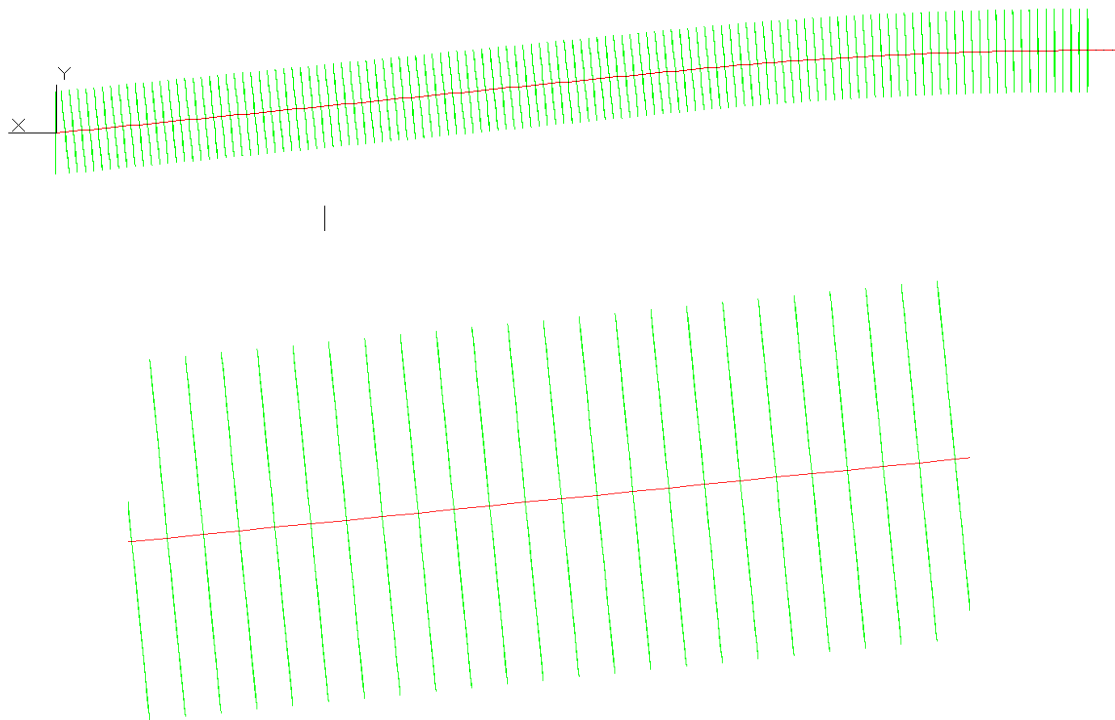
- ☒ Vertical
- ☐ Perpendicular to vt. alignment

Point code database

Vertical cross-sections



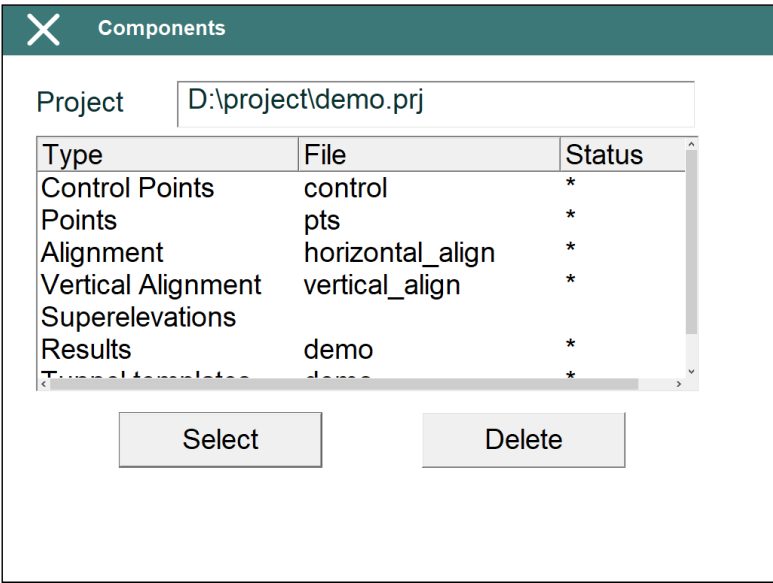
Sloped cross-sections (perpendicular to vertical alignment)



Also, it shows information about the *Name* and *Author* of the project and the name of current code database.

2.2. Components

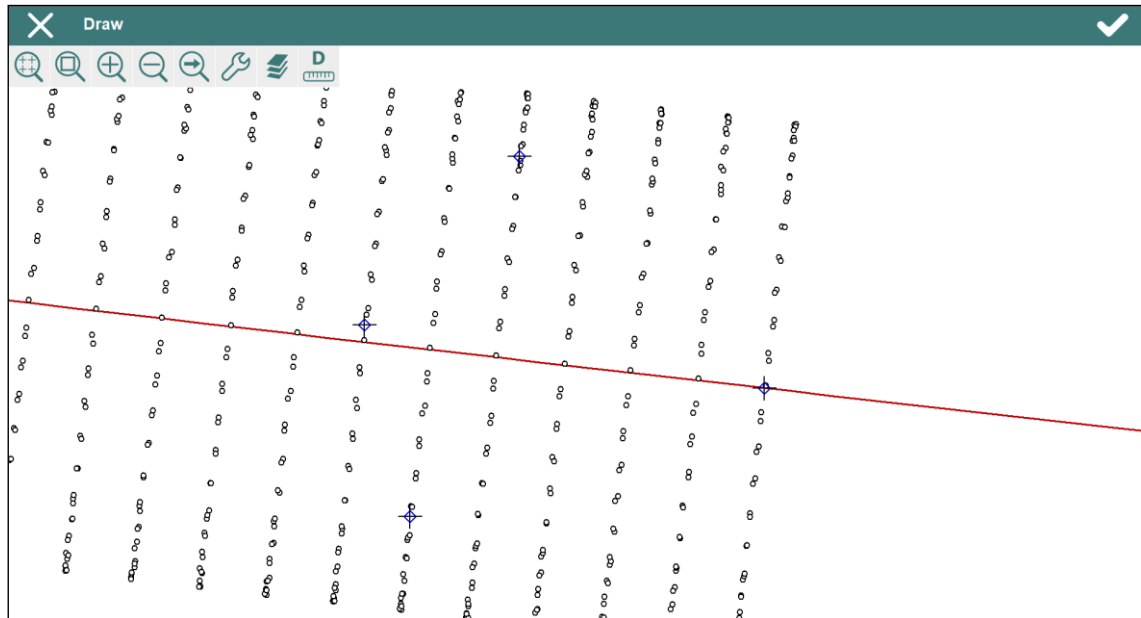
Shows a list containing the names of all the files assigned to the active project, which are differentiated by type.



Non-specific file categories can be selected from the dialog box, and any of them be deleted from the project. In order to do so, you must click on the file *type* desired and click on *Select* or *Delete*.

2.3. Draw

Allows one to draw the components of the project in top view.



2.4. Select

Allows one to choose a previously saved project.

2.5. New

Allows one to create an empty project. A name should be assigned to the project and the properties described in the **Properties** section should be set.

2.6. Delete

Allows one to delete an existing project. The currently selected project cannot be deleted.

2.7. File Management

The application has a file management menu that supports the following kinds of files:

Extension	Description	TcpMDT Compatible
BSE	Control points / Standing stations	YES
EJE	Horizontal alignment	YES
RAS	Vertical alignment	YES
PER	Superelevations	YES
TNL	Tunnel templates	NO
PUN	Surveying points	YES

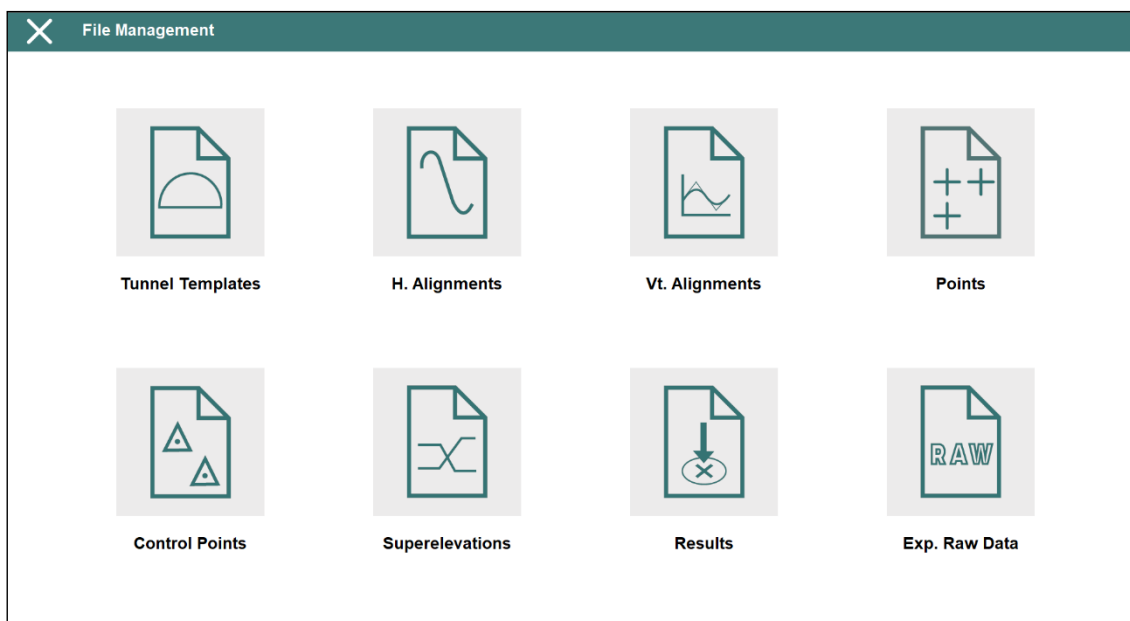
RES	Setting out results	NO
PRJ	Projects	NO
ASG	Tunnel template assignments	NO

The work files can be directly copied to the mobile device using Windows file explorer.

All the options check for the existence or not of the files needed for the calculations and indicate an error message should they not exist.









The characteristics of each of the files types and the way they are managed are explained in next section.

3. File Management



3.1. Common Functions

The following functions are common to most of the edit and drawing dialogs each type of file:

-  View first record in file.
-  Go back one position from current record.
-  Go forward one position from current record.
-  View last record in file.
-  Create a new record with blank data.
-  Deletes the selected records. Permits multiple selection.
-  Finds a record that meets certain criteria.
-  Undoes the last change of the selected cell.



Shows complete extension of drawing.



Enlarges an area set by a window defined by two opposite points.



Enlarges drawing's level of detail.



Reduces drawing's level of detail.



Shows previous view.



Enables drawing properties to be changed.



Enables drawing layers to be activated or deactivated.



Displays information about the selected element.



Enables the menu that allows one to calculate areas and distances.



Adds the points selected for calculating areas and distances.



Deletes the last point selected for calculating areas and distances.

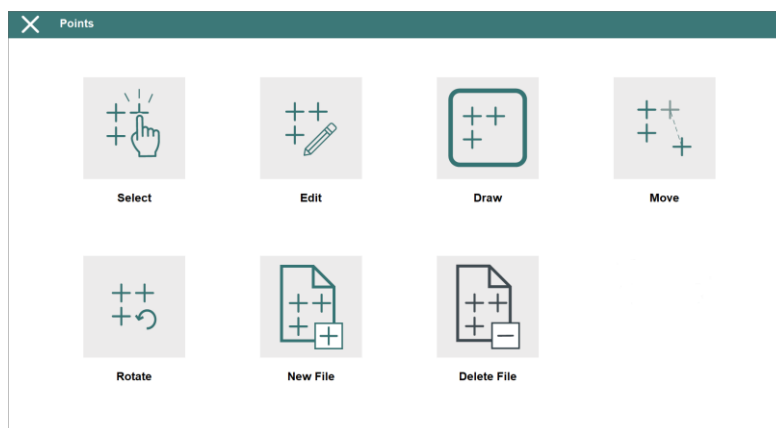


Calculates area and distance with the selected points.



Disables the area and distance calculation menu.

3.2. Points



All surveying points of the current project are stored in these files in ASCII format. These files have the *.PUN extension (compatible with **TcpMDT** and **TcpTunnel CAD**) and contain the following data for each point:

<Number> <X Coordinate> <Y Coordinate> <Z Coordinate> <Code>

A points file is automatically created whenever a project is created. It has the same name as the project and has the aforementioned extension.

The program allows for repeated points, as well as points having alphanumeric numbering.

The field separator can be a space, a tab or a comma.

The names and codes cannot include blank spaces.

3.2.1. Select

Allows one to select a points file from already existing files.

3.2.2. Edit

Allows one to view and modify the current file's records.

The screenshot shows a window titled 'pts.pun' with a dark green header bar containing a close button (X), a dropdown arrow, and a checkmark. Below the header is a table with the following data:

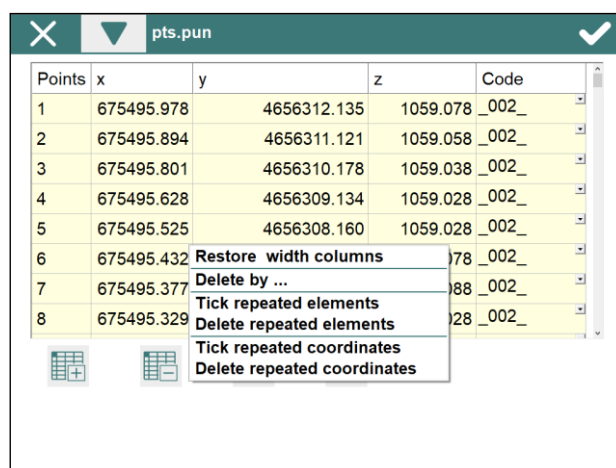
Points	x	y	z	Code
1	675495.978	4656312.135	1059.078	_002_
2	675495.894	4656311.121	1059.058	_002_
3	675495.801	4656310.178	1059.038	_002_
4	675495.628	4656309.134	1059.028	_002_
5	675495.525	4656308.160	1059.028	_002_
6	675495.432	4656307.167	1059.078	_002_
7	675495.377	4656306.693	1059.088	_002_
8	675495.329	4656306.203	1059.028	_002_

Below the table are four icons: a grid, a list, a search, and a zoom.

The records have the following fields:

Name	Type	Length	No. of Decimals	Remarks
N	Alphanumeric	256	0	Point number
X	Numeric	11	3	
Y	Numeric	11	3	
Z	Numeric	8	3	
Code	Alphanumeric	256	-	Optional

Apart from the button-based options, other options are available through this window's title bar menu:

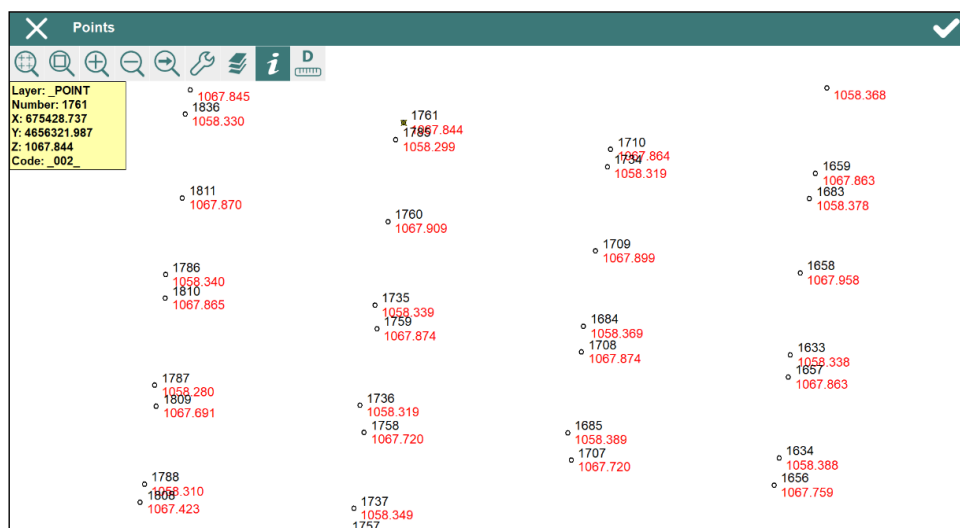


The **Delete by...** option shows a new dialog where the user can select the items to be deleted. The selection can be made indicating a range of numbers (**Select by Numbers**) or by entering a code (**Select by Code**)

The other options allow user to restore the default width of columns and locate and remove points that have the same number or coordinates.

3.2.3. Draw

Allows one to draw the current file's points, including break lines should they exist.



3.2.4. Move

This tool enables one to move a set of previously selected points to some specific coordinates.

The points one wishes to displace should first be selected. They can be selected by either indicating a range of numbers (*Selection by Numbers*) or entering a code (*Selection by Code*).

The following data is then requested:

By coordinates

By offsets

Move Points

Source

X: 675495.978

Y: 4656312.135

Z: 1059.078

Type

☐ Absolute

☒ Relative

Target

X Offset:

Y Offset:

Z Offset:

Source: *X, Y, Z* coordinates of the base point. The button allows one to select the point in different ways.

Target: The destination coordinates should be specified depending on the source set, as should the kind of movement selected.

Type: One has to select either *Absolute* or *Relative* movement. Depending on the selection made, either *Coordinates* or *Offset* will appear in the **Target** box.

3.2.5. Rotate

This tool produces a rotation of a specific angle for the points selected.

A window appears where the points one wishes to rotate should be selected when this command is run.

Select Points

Select by Numbers

Initial Num.: 1

Final Num.: 100

Select by Codes

Code:

100 Points selected

Once the points are selected, the following data is requested:

Rotate Points

Source

x 675495.978

y 4656312.135

Angle 125.0

Source: The base points coordinates should be entered either manually or by clicking on the button.

Angle: Indicates the angle of rotation for the points selected.

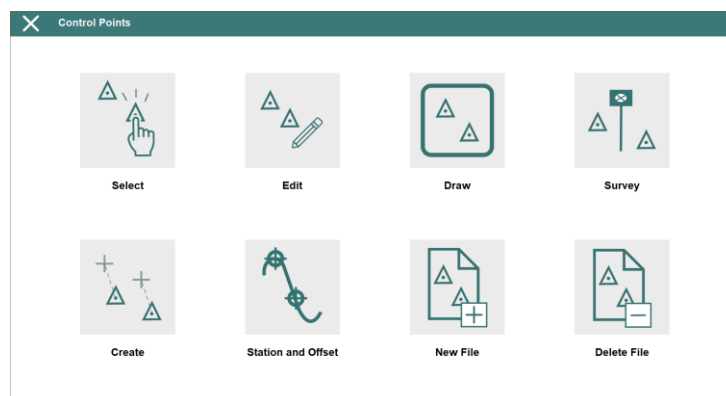
3.2.6. New File

Creates an empty points file and associates it with the active project.

3.2.7. Delete File

Deletes a points file from the field data recorder. If the file selected belongs to the active project, the link to the project is also deleted.

3.3. Control Points



Control points of the current project are stored in these files in ASCII format. These files have the *.BSE extension (compatible with **TcpMDT** and **TcpTunnel CAD**) and contain the following data for each station:

<Number> <X Coordinate> <Y Coordinate> <Z Coordinate> <Anamorphosis> <Code>

A stations file is automatically created whenever a project is created. It has the same name as the project with the aforementioned extension.

The field separator can be a space, a tab or a comma.

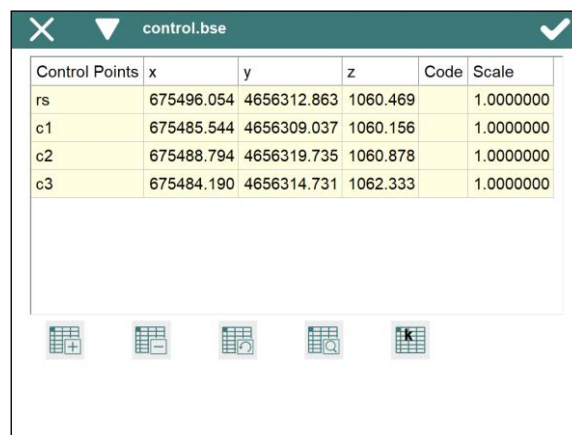
The names and codes cannot include blank spaces.

3.3.1. Select

Allows one to select a stations file.

3.3.2. Edit

Allows one to view and modify the current file's records.




The screenshot shows a window titled 'control.bse' with a table of control points. The table has columns: Control Points, x, y, z, Code, and Scale. The data rows are as follows:

Control Points	x	y	z	Code	Scale
rs	675496.054	4656312.863	1060.469		1.0000000
c1	675485.544	4656309.037	1060.156		1.0000000
c2	675488.794	4656319.735	1060.878		1.0000000
c3	675484.190	4656314.731	1062.333		1.0000000

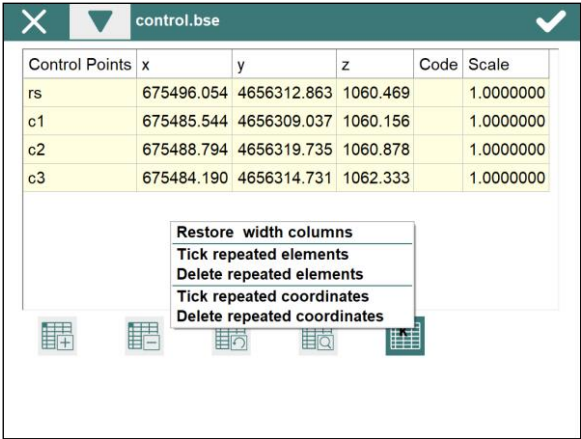
Below the table, there are five icons: a grid with a plus sign, a grid with a minus sign, a grid with a magnifying glass, a grid with a cursor, and a grid with a key.

The records are made up of the following fields:

Name	Type	Length	No. of Decimals	Remarks
Control Point	Alphanumeric	64	-	Name of the control point
X	Numeric	11	3	
Y	Numeric	11	3	
Z	Numeric	8	3	
Code	Alphanumeric	256	-	Optional
Scale	Numeric	9	8	

The  button calculates the current station's anamorphosis based on WGS-84 datum.

Apart from the button-based options, other options are available through this window's title bar menu:



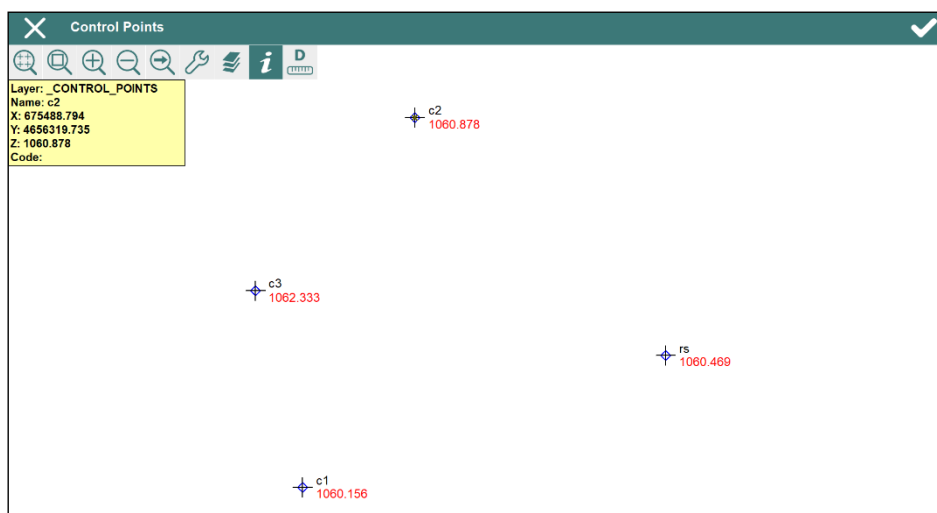
Control Points	x	y	z	Code	Scale
rs	675496.054	4656312.863	1060.469		1.0000000
c1	675485.544	4656309.037	1060.156		1.0000000
c2	675488.794	4656319.735	1060.878		1.0000000
c3	675484.190	4656314.731	1062.333		1.0000000

Restore width columns
 Tick repeated elements
 Delete repeated elements
 Tick repeated coordinates
 Delete repeated coordinates

These options allow user to restore the default width of columns and locate and remove points that have the same number or coordinates.

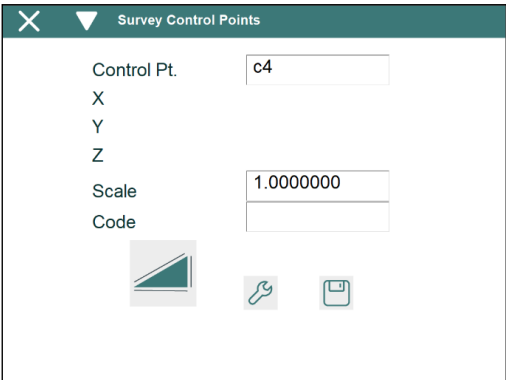
3.3.3. Draw

Shows a drawing with the control points stored in the current file.



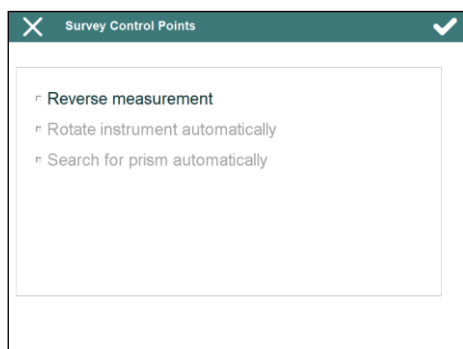
3.3.4. Survey

Allows one to create a control point from a point measured from the total station.



The 'Survey Control Points' window contains input fields for: Control Pt. (c4), X, Y, Z, Scale (1.0000000), and Code. At the bottom, there are icons for a surveying instrument, a wrench, and a save icon.

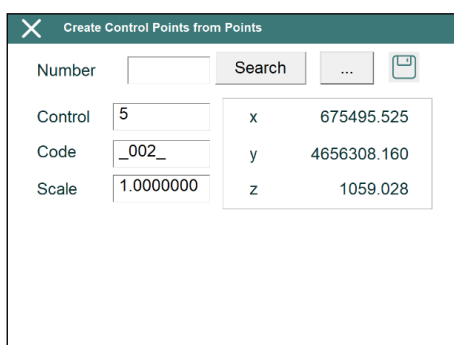
The measurements can be done with reverse option, rotating the instrument automatically with motorized total stations. These parameters are available through Settings option of the menu of the title bar.





3.3.5. Create

Permits one to create a control point in two different ways:

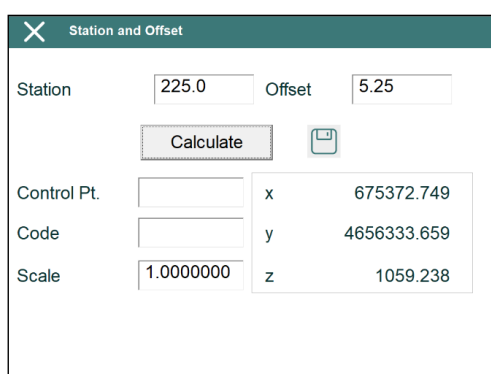
From points




The number of the desired point should be entered in the **Number** box and the **Search** button or the  button should be clicked and the point selected from the list shown. The button  adds the control point to the selected file.

Entering the code is not obligatory.

Station and Offset



The coordinates of a new control point are shown on screen by entering a **Station**(chainage) and **Offset** and clicking on the **Calculate** button. A name should be entered for the control point and the  button clicked to save the data.

If the project does not have a vertical alignment file, it is saved with a height equivalent to 0.0.

Entering the code is not obligatory.

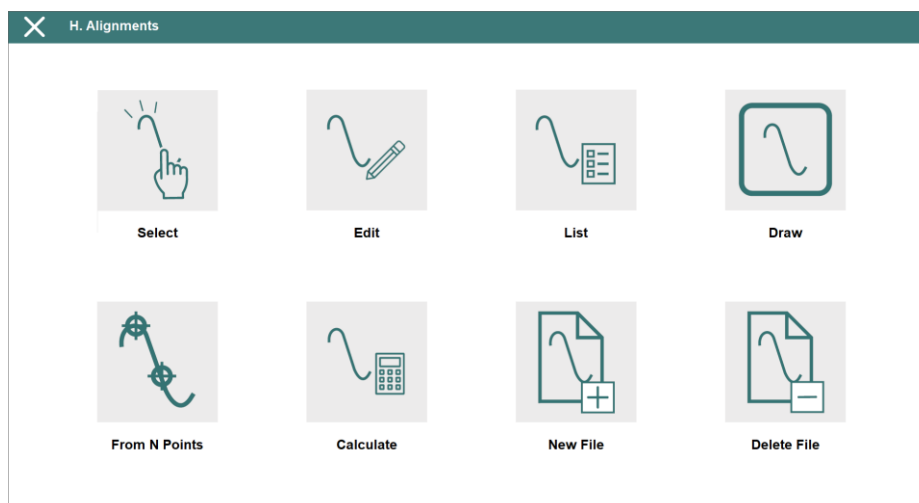
3.3.6. New File

Creates an empty control point file.

3.3.7. Delete File

Deletes a control point file from the disk. If it belongs to the current project, the link to the project is also deleted.

3.4. Horizontal Alignments



These files have *.EJE extension and are compatible with **TcpMDT** and **TcpTunnel** CAD files.

3.4.1. Select

Allows one to select a horizontal alignment file.

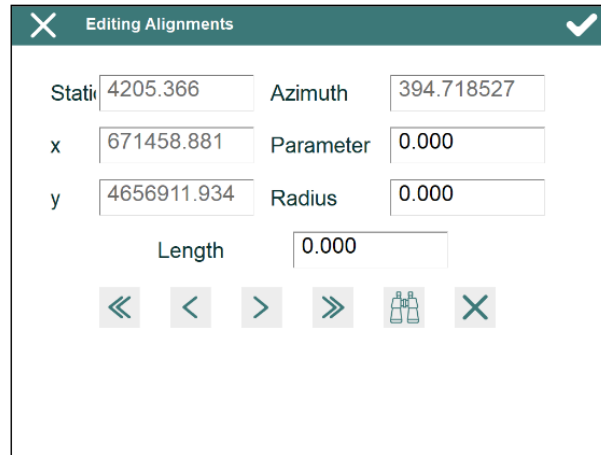
3.4.2. Edit

Allows one to view and modify the of the current file's records. If one changes a field of any vertex and presses the next or previous button, all the vertexes of the alignment will be recalculated.

One can also insert an alignment manually, by inserting all the data of the initial vertex and pushing the next button. The data of the next vertex will be calculated automatically.

The process must be repeated for each of the alignment's vertices. The program will add a new vertex whenever a length other than 0.0 is indicated.

To record the data to file, press the accept button when all the vertices have been entered.




The 'Editing Alignments' dialog box contains the following fields and controls:

- Station: 4205.366
- Azimuth: 394.718527
- x: 671458.881
- Parameter: 0.000
- y: 4656911.934
- Radius: 0.000
- Length: 0.000
- Navigation buttons: <<, <, >, >>, and a button with a magnifying glass icon.
- Accept button: A button with a checkmark icon.

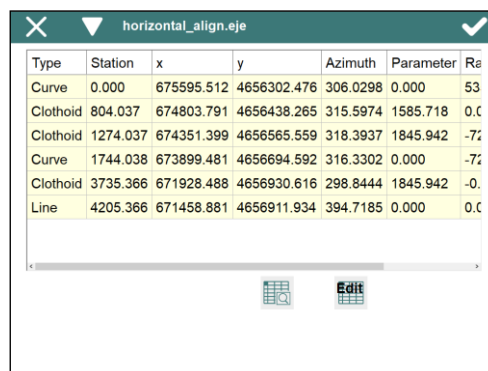
The records have the following fields:

Name	Type	Length	No. of Decimals	Remarks
Station	Numeric	11	3	Kilometer point
X	Numeric	11	3	
Y	Numeric	11	3	
Azimuth	Numeric	8	4	
Parameter	Numeric	9	3	Clothoid section parameter
Radius	Numeric	9	3	

The  button allows one to search for a specific station.

3.4.3. List

Displays a list of the alignment's vertices. One cannot add or edit vertices in this window. To do so, press the **Edit** button.



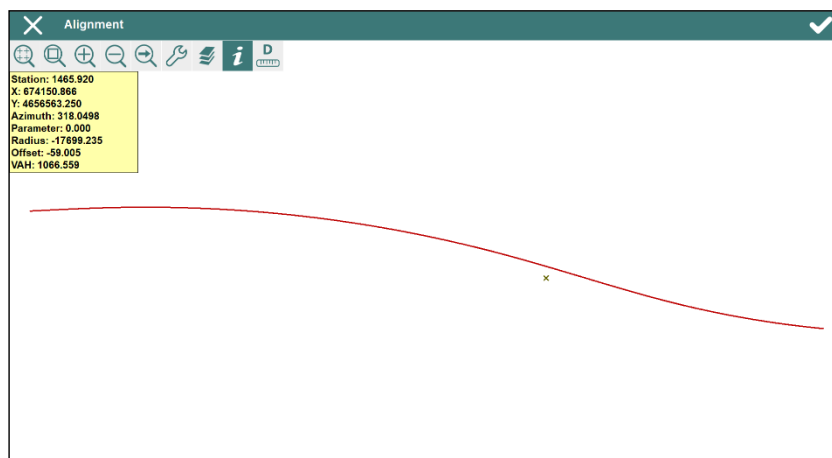
The 'horizontal_align.eje' window displays a table of alignment vertices:

Type	Station	x	y	Azimuth	Parameter	Radius
Curve	0.000	675595.512	4656302.476	306.0298	0.000	53
Clothoid	804.037	674803.791	4656438.265	315.5974	1585.718	0.0
Clothoid	1274.037	674351.399	4656565.559	318.3937	1845.942	-7
Curve	1744.038	673899.481	4656694.592	316.3302	0.000	-7
Clothoid	3735.366	671928.488	4656930.616	298.8444	1845.942	-0.
Line	4205.366	671458.881	4656911.934	394.7185	0.000	0.0

At the bottom of the window, there are two buttons: a button with a magnifying glass icon and a button labeled 'Edit'.

3.4.4. Draw

Shows a drawing of the project alignment.



3.4.5. Create Alignment from N Points

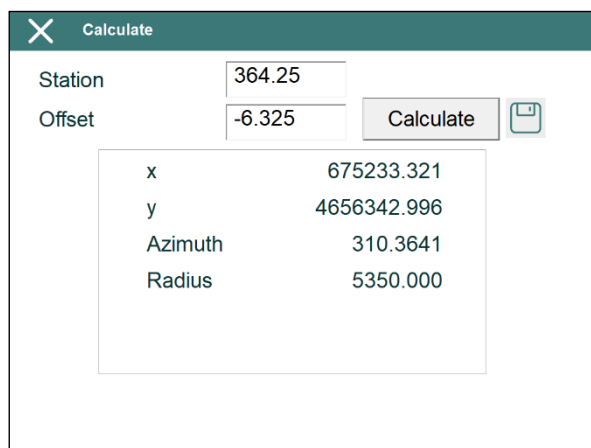
Allows one to create an alignment and the associated vertical alignment by supplying N points and an *Initial Station*.

First, the program asks for the names of the alignment and vertical alignment files.

The screenshot shows a software window titled 'From N Points'. It has a toolbar with zoom and edit icons. Below the toolbar is an 'Initial Sta.' input field. Underneath is a table with four columns: 'Point', 'x', 'y', and 'z'. The table is currently empty. At the bottom of the window are two buttons: 'Insert' and 'Delete'.

3.4.6. Calculate

If one supplies a *Station* and an *Offset* and pressing the *Calculate* button, the program displays the *x* and *y* coordinates of the calculated point, as well as the *Azimuth* and *Radius* of the alignment in the Station in question.



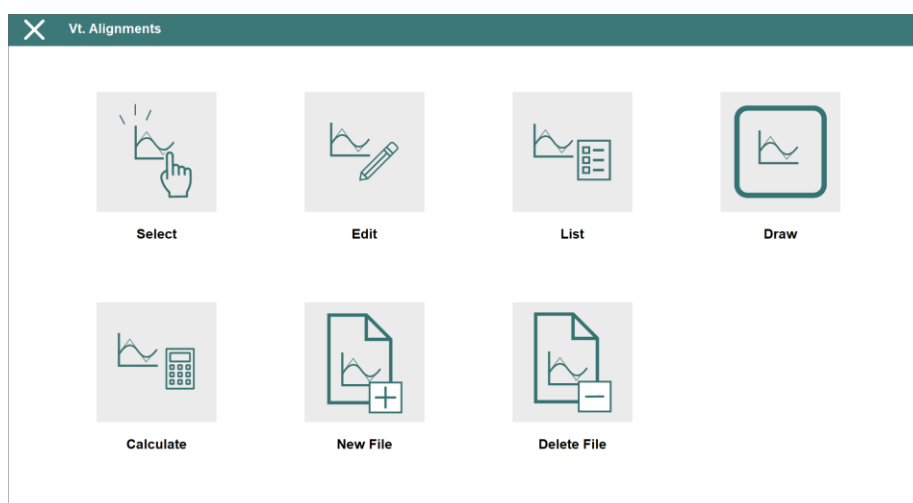
3.4.7. New File

Creates an empty horizontal alignment file.

3.4.8. Delete File

Deletes a horizontal alignment file from the disk. If it belongs to the current project, the link to the project is also deleted.

3.5. Vertical Alignments



Grade lines are vertical alignments comprising the final status of a longitudinal profile. They involve certain distances to origin and their absolute heights, with the possibility of linking the vertices by means of parabolic or circular sections (vertical transition curves) which will be defined by any of their components: **K_v** (parameter of the parabola) or **R** (radius of the circle), **Tangent** (length in an orthogonal projection on each of the alignments involved) or **Arrow** (maximum ordinate at the vertex).

TcpTunnel works indistinctly with parabolic or circular curves.

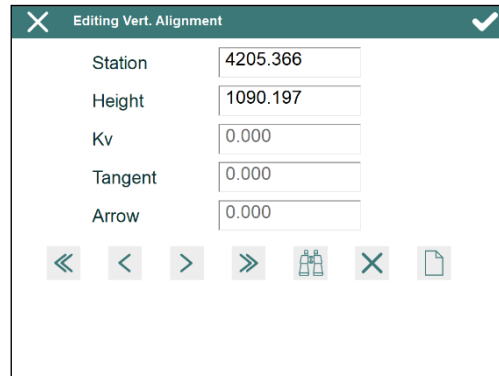
These files have *.RAS extension and are compatible with **TcpMDT** and **TcpTunnel CAD** files.

3.5.1. Select

Allows one to select a vertical alignment file.

3.5.2. Edit

Allows one to view and modify the current file's records.



The **Kv** or **Radius**, the tangent and the arrow are automatically calculated in manual entry when one of them is entered. Depending on the type of vertical alignment file's transition curve, the **Kv** (parabolic transition curve) or **Radius** (circular transition curve) is shown on screen.

In addition to the common file management options, the ones appearing below are available:



Insert a new vertex.



Looking for a station.

The records have the following fields:

Name	Type	Length	No. of Decimals	Description
Station	Numeric	11	3	Kilometer point
Height	Numeric	8	3	Vertex height
Kv / Radius	Numeric	9	3	
Tangent	Numeric	9	3	
Arrow	Numeric	9	3	

3.5.3. List

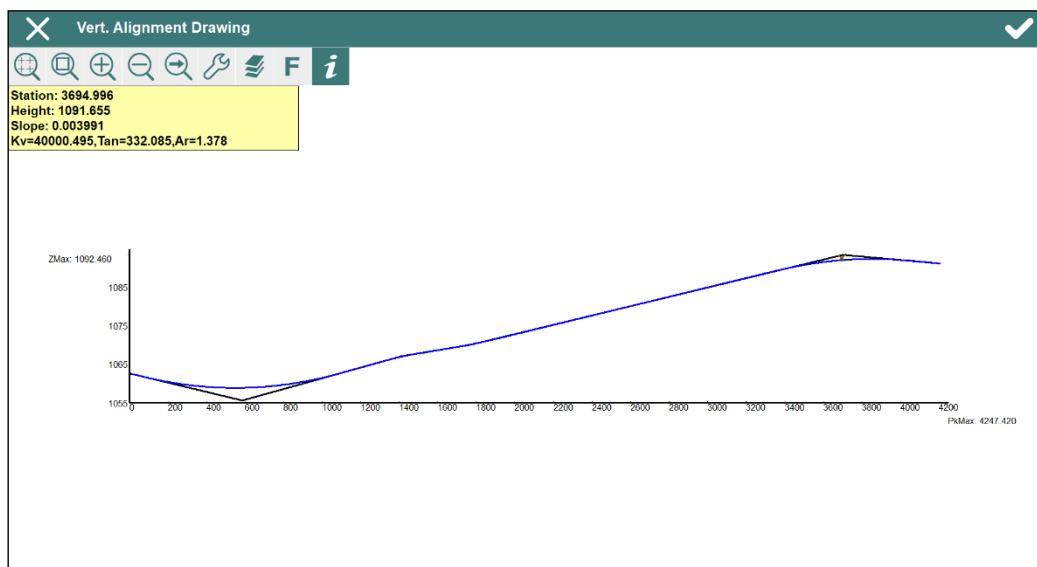
Shows a list with the vertical alignment vertices.

vertical_align.ras				
Station	Height	Kv	Tangent	Arrow
0.000	1061.674	0.000	0.0000	0.000
585.410	1054.561	39250.069	0.0000	3.355
1413.294	1066.152	32004.090	92.7590	0.134
1772.294	1069.097	45004.492	87.7520	0.086
3702.571	1092.460	40000.495	332.0850	1.378
4205.366	1090.197	0.000	0.0000	0.000

3.5.4. Draw

Shows a drawing of the current vertical alignment. Should transition curves be defined, both the previous vertical alignment as well as the definitive vertical alignment will be drawn.

Information about the station selected, the slope of the section to which the said station belongs and the height are shown by clicking on the screen. If the point selected projects onto any of the transition curves defined, the kv/radius, the tangent and the corresponding arrow will additionally be shown.

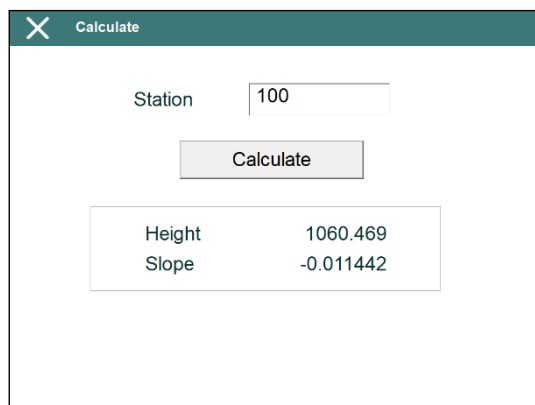


The button with the letter **F** allows different scale values for the drawing.

Factor	
Factor	<input type="text" value="5"/>

3.5.5. Calculate

Entering a *Station* and clicking the *Calculate* button shows the corresponding height and the slope of the section to which the said station belongs on screen.



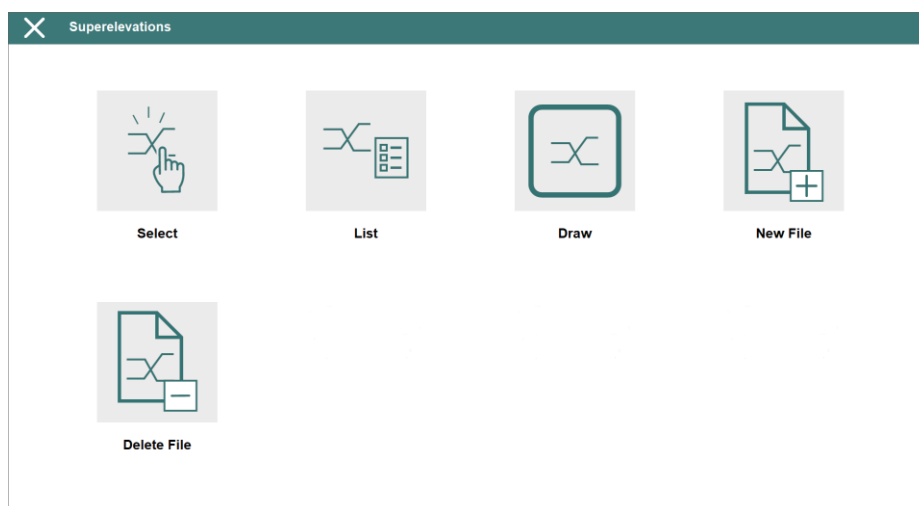
3.5.6. New File

Creates an empty vertical alignment file and associates it to the current project.

3.5.7. Delete File

Deletes a vertical alignment file from the disk. If the file selected belongs to the active project, the link to the project is also deleted.

3.6. Superelevations



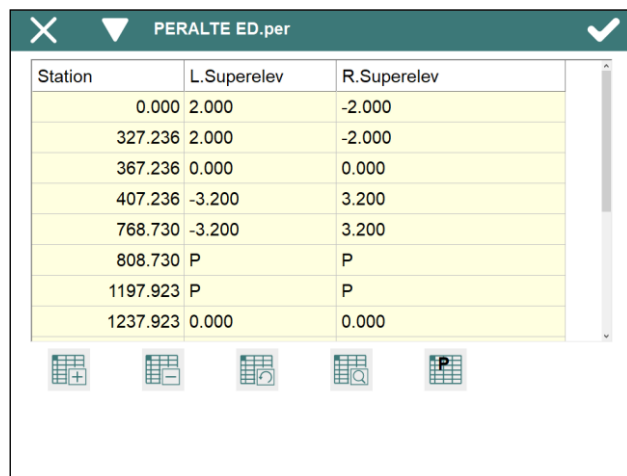
These files contains the superelevations of the project to rotate the tunnel template or to apply to the height when staking out roadbed. They have *.PER extension and are compatible with **TcpMDT** and **TcpTunnel CAD** files.

3.6.1. Select

Allows one to select a superelevation file.

3.6.2. List

Allows one to view and modify the current file's records.



Station	L.Superelev	R.Superelev
0.000	2.000	-2.000
327.236	2.000	-2.000
367.236	0.000	0.000
407.236	-3.200	3.200
768.730	-3.200	3.200
808.730	P	P
1197.923	P	P
1237.923	0.000	0.000

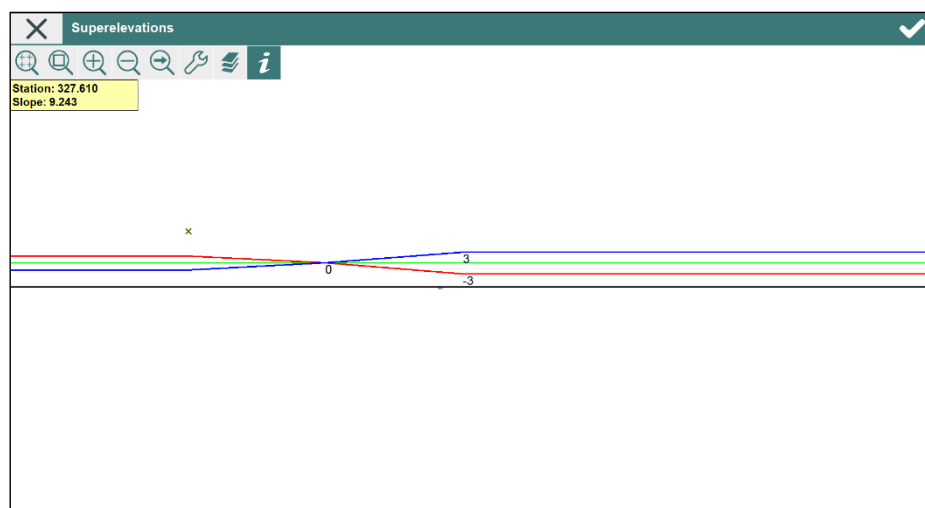
The records have the following fields:

Name	Type	Length	No. of Decimals	Remarks
Station	Numeric	11	3	Kilometer point
L.S.	Numeric	6	3	Left-hand superelevation
R.S.	Numeric	6	3	Right-hand superelevation

If the value of the right-hand and left-hand side superelevations is **P**, it indicates that there is pumping. In other words the value of both superelevations is -2.0% .

3.6.3. Draw

Shows the graphic of the current superelevation file.



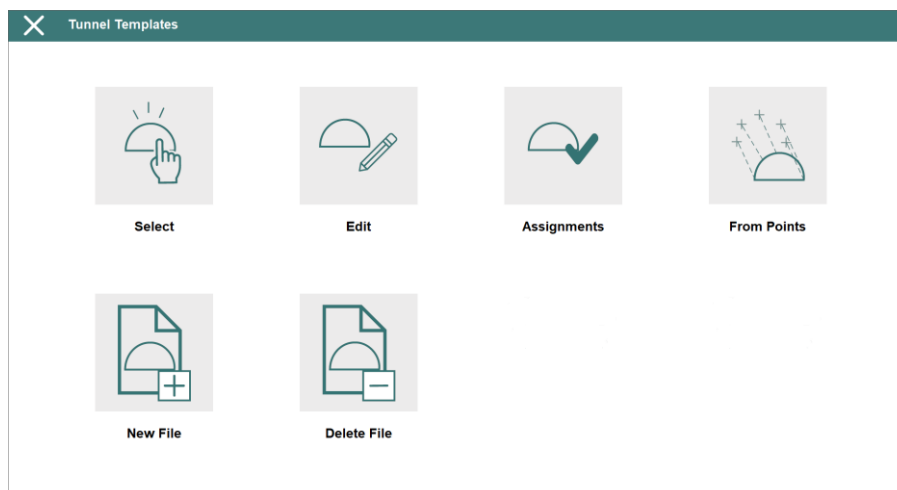
3.6.4. New File

Creates an empty superelevation file.

3.6.5. Delete File

Deletes a superelevation file from the disk. If the file selected belongs to the active project, the link to the project is also deleted.

3.7. Tunnel Templates



These files have *.TNL extension and are compatible with **TcpTunnel CAD**.

The application allows one to work with 3 kinds of cross-sections:

Simple template: A circular template defined from a radius.

Compound template: Defined from a radius and sidewalls.

Complex template: Defined by a succession of curved and straight sections.

Of these, only the first two can be defined in the field data recorder itself. Complex cross-sections have to be created in TcpTunnel CAD program. All cross-sections created in this module will be treated by the application as if they were complex, even if they are simple or composite cross-sections.

Said cross-sections can be included or not in the road surface or inverted arch zones. They will be considered as **Open** if they do not include them and **Closed** otherwise. The kind of cross-section one wishes to create has to be indicated in the field data recorder, while in CAD it is done automatically depending on whether the polyline created is open or closed.

The cross-section center and three distances marking where the alignment is marked on the ground plan, the vertical alignment and the superelevations will be requested in all cases. One must additionally specify how the cross-section varies as a function of the superelevations (see **Edit** section).

The vertical alignment and superelevation application point should be within the tunnel cross-section.

All the data referring to cross-sections requested and shown in the application are understood to be in the forward direction of stations on the project's alignment.

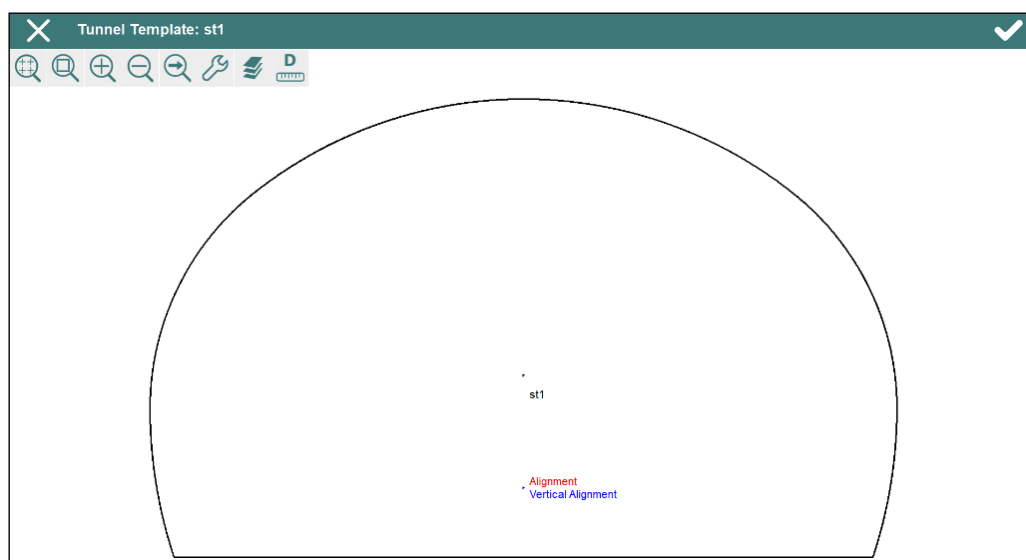
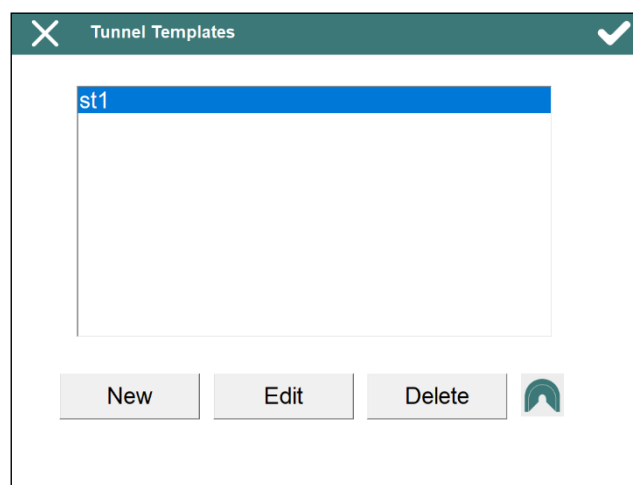
The survey and set out profiles, set out front and position options allow one to divide the section into specific theoretical points starting off from the keystone up to the values indicated to the left and the right of the keystone. Exclusion zones can be defined. See **Features and Functionality > [Theoretical Points of the Tunnel Template](#)**.

3.7.1. Select

Allows one to select a tunnel template file in the current project.

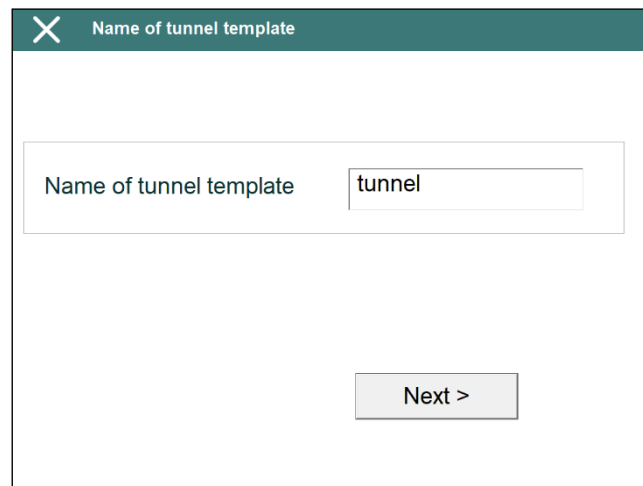
3.7.2. Edit

Allows one to view and delete templates of all the types supported, in addition to editing and creating simple and composite cross-sections.

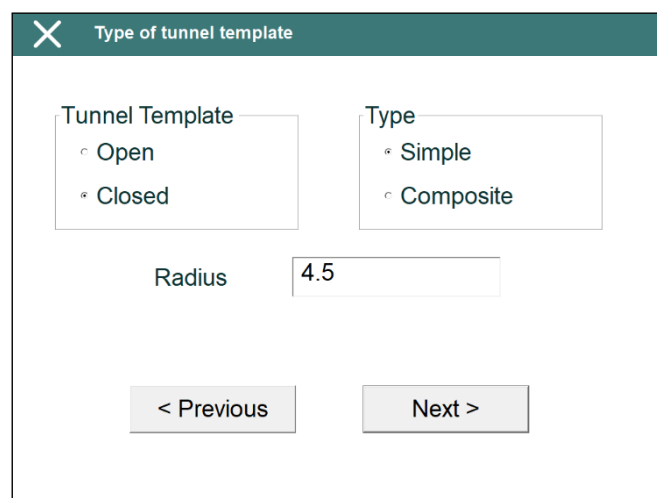


A wizard to edit and create templates is shown. It provides detailed information on all the parameters that define tunnel's template.

Name of the tunnel template:



Type of tunnel template:



Only the **Radius** value should be entered for simple cross-sections, while **Radius** and **Sidewall** length should be entered for composite cross-sections. In the latter case, the cross-section will be created with straight sidewalls that start at the left-hand and right-hand points of the semi-circle having the radius indicated.

Both types of cross-sections can be created **Closed** or **Open**. In the latter, the right and left-hand limits are marked by the vertical alignment and superelevation application point.

Application Points:

The tunnel cross-section center's coordinates should be entered in this section, as should the series of distances described below. It should be taken into account that the

intersection point between the vertical straight line passing through the center thus defined and the tunnel cross-section will be considered as the keystone.

Application Points

Center of tunnel template

X: 0.000

Y: 0.000

Vt. keystone to vt. align. dist.: 4.5

H. alignment to center dist.: 0.000

Vt. align. to alignment dist.: 0.000

< Previous Next >

Vertical keystone to vertical alignment distance: A positive value should be indicated if the keystone point is above the vertical alignment and superelevation application point and negative otherwise. Under normal conditions, this value should always be positive. The vertical alignment and superelevation application point should be within the tunnel template.

Horizontal alignment to center distance: A positive value indicates that the horizontal alignment is to the right of the cross-section's center and a negative value indicates it is to the left. Differently to the vertical alignment and superelevation application point, the horizontal alignment's application point can be defined to be outside the tunnel template.

Vertical alignment to alignment distance: In this case the reference is the horizontal alignment's application point. One will therefore have to indicate a positive value if the vertical alignment and superelevation application point is to the right of the alignment and a negative value if it is to the left.

Advanced (Superelevations):

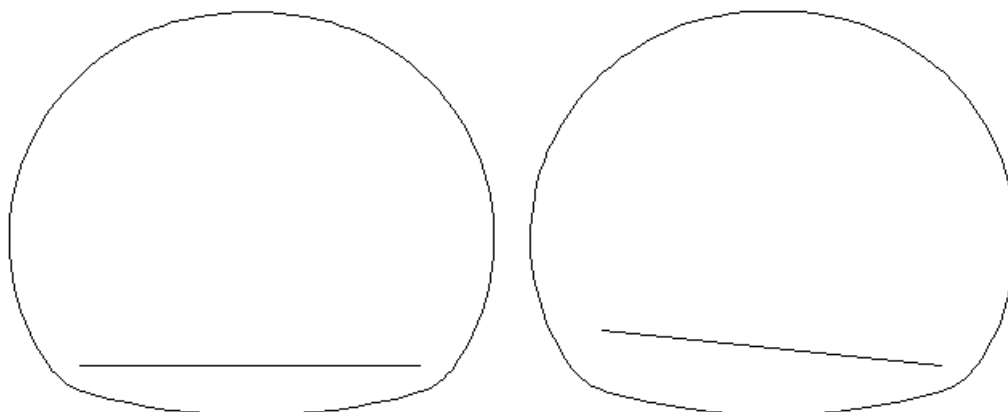
In the last section of the wizard, one should indicate how the template behaves depending on the project's superelevations.

Advanced (Superelevations)

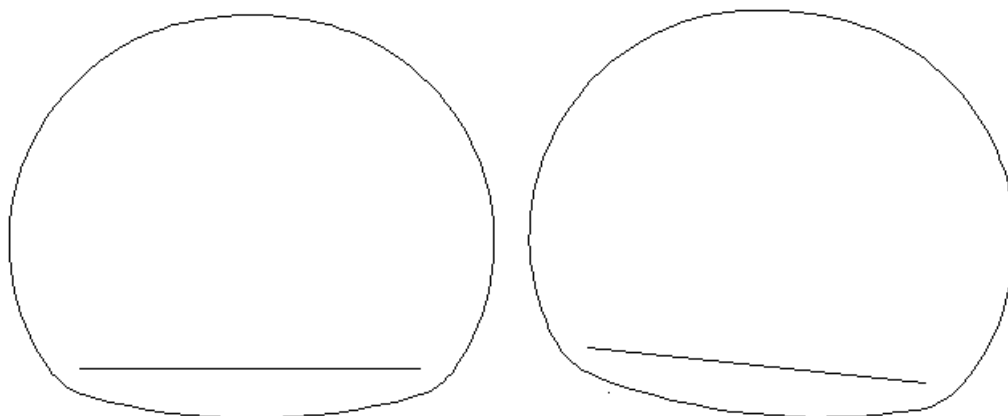
☒ Keep tunnel template fixed
☐ Tilt tunnel template

< Previous Finish

Keep tunnel template fixed: The tunnel template doesn't rotate with superelevations.



Tilt tunnel template: Taking the pivot point to be the point where the vertical alignment and superelevations are applied, the cross-section will tilt according to the superelevation of the station in question. This superelevation is calculated by averaging the superelevations on the left and right.



3.7.3. Tunnel Template Assignment

Allows one to indicate which templates will be used along the length of the project's horizontal alignment.

×

Tunnel Templates Assignment

✓

Assignments

4205.366 st1

Tunnel Templates

st1

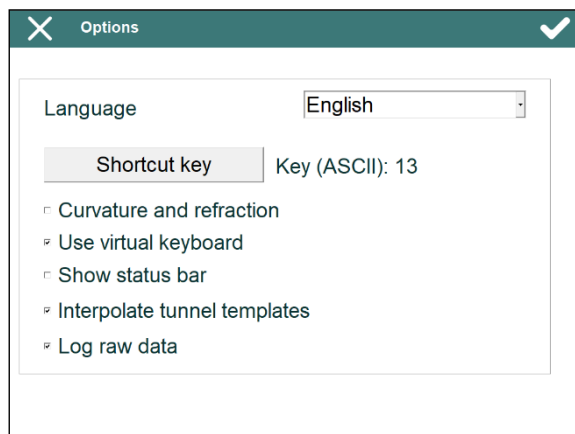
Final Sta.

4205.366

Insert

Delete

Should various templates be assigned, the program will interpolate between them, if it is well established in **Settings > Options**.



The names of all the templates in the current file appear on the **Tunnel Templates** list.

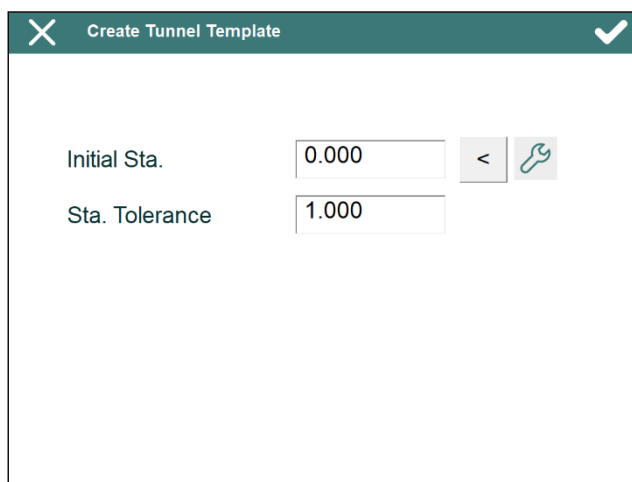
The last station of the current project's alignment initially appears in the **Final Station** box.

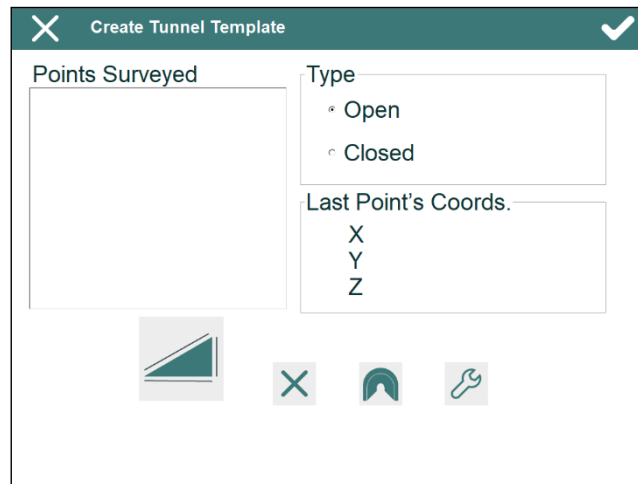
In order to create an assignment, you should select the template name in the **Templates** list, indicate the final station up to where the template will be used and click on the **Insert** button. In the example shown on screen, **2** is used from the initial station of the alignment up to station 10.000.

In order to delete an assignment, you must select it from **Assignments** list and click on the **Delete** button.

3.7.4. Create from Points



Allows one to create an **Open** or **Closed** template from the points taken within the range of stations initially defined by **Initial Station** and **Station Tolerance**.





The *X*, *Y* and *Z* coordinates are shown for each point observed.

The numbers of the measured points are shown in the *Points* list.

The tunnel template being created can be viewed at all time pressing  button, and any point not desired can be deleted pressing  button.

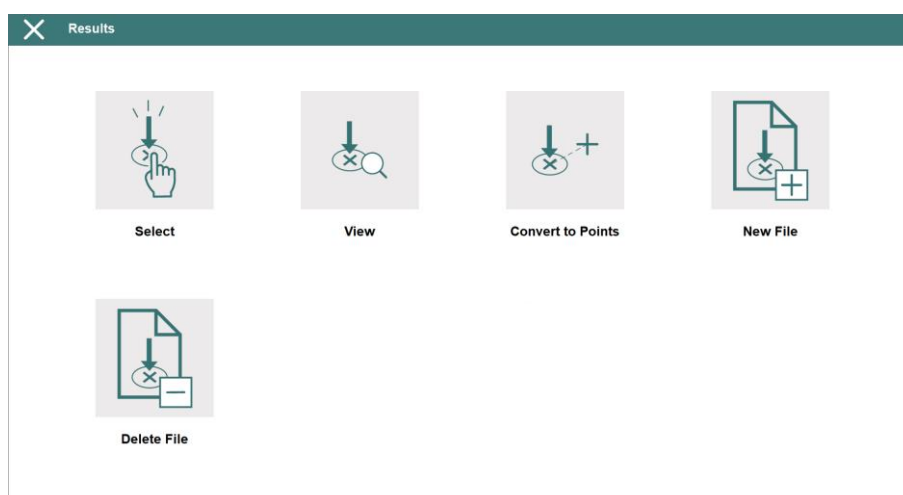
3.7.5. New File

Creates an empty tunnel templates file.

3.7.6. Delete File

Deletes a tunnel templates file from the disk. If the file selected belongs to the active project, the link to the project is also deleted.

3.8. Results



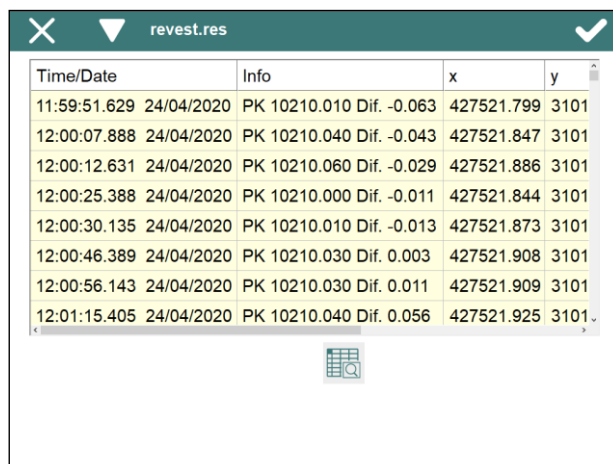
These are files that store the information on the points set out. They are automatically created when the project is created and have the same name as the project with the extension *.RES.

3.8.1. Select

Allows one to select a results file.

3.8.2. View

Allows one to view the information on the points set out.



Time/Date	Info	x	y
11:59:51.629 24/04/2020	PK 10210.010 Dif. -0.063	427521.799	3101
12:00:07.888 24/04/2020	PK 10210.040 Dif. -0.043	427521.847	3101
12:00:12.631 24/04/2020	PK 10210.060 Dif. -0.029	427521.886	3101
12:00:25.388 24/04/2020	PK 10210.000 Dif. -0.011	427521.844	3101
12:00:30.135 24/04/2020	PK 10210.010 Dif. -0.013	427521.873	3101
12:00:46.389 24/04/2020	PK 10210.030 Dif. 0.003	427521.908	3101
12:00:56.143 24/04/2020	PK 10210.030 Dif. 0.011	427521.909	3101
12:01:15.405 24/04/2020	PK 10210.040 Dif. 0.056	427521.925	3101

- **Time/Date** in which the point was set out.
- **Info**: Data on the point set out depending on the setting out option selected.
- **X, Y, Z** coordinates of the point set out.
- **Code** assigned to the point set out.
- **X, Y, Z** differences between the theoretical setting out point and the point set out.

3.8.3. Convert to Points

Allows one to export the coordinates of all the points set out to a points file.

The points are numbered starting with 1 for the first.

If the selected file exists, it will be overwritten.

The code will be formed by the code entered when setting out the point, followed by the data of the point set out in brackets.

3.8.4. New File

Creates an empty results file.

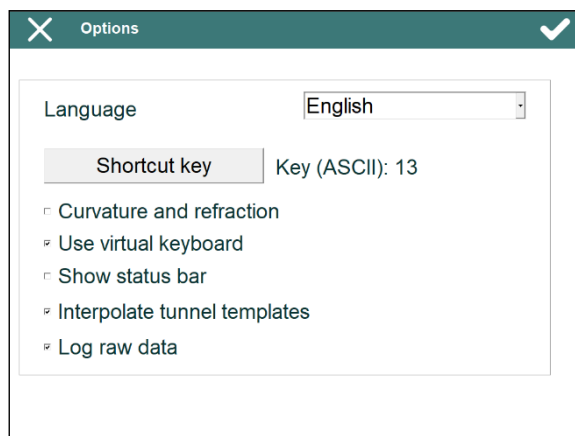
3.8.5. Delete File

Deletes a results file from the disk. If the file selected belongs to the active project, the link to the project is also deleted.

3.9. Raw Data

The program allows one to enable the storing of all information regarding with measured data in an ASCII file. This file is created for each Project and it is stored in its folder with the name **LogTS.txt**. Each time the file size exceeds 2MB, a new file is created with the name **LogTS_N.txt**, where **N** is 1, initially, and its value is increased by 1 unit. For instance, LogTS.txt, LogTS_1.txt, LogTS_2.txt.

The recording of these data is optional, and it can be disabled within **Settings > Options**.



The content of this kind of file is as follow:

File version:

#V 1

Project name:

#Project \ROMDisk\demo\demo.prj

Name of the fields of stored information:

#Date #Time #Code #Option Name ...

Information of the project properties:

***12/11/2015 10:55:16.000 Project properties Sloped profiles: 0**

This information is stored when the file is created and, also, every time that project properties screen is validated.

The program stores date and time and the method used for creating tunnel templates.

Measurement data:

12/11/2015 12:51:36.000 _002_ Survey_cross_sections cp1...

○ Date

○ Time

- Code of the program option
 - _001_ : Survey > Grid**
 - _002_ : Survey > Cross-Sections**
 - _003_ : Survey > Points**
 - _004_ : Checking > Cross-Sections**
 - _005_ : Setting Out > Front**
 - _006_ : Setting Out > Cross-Sections**
 - _007_ : Setting Out > Road Surface**
 - _008_ : Setting Out > Points**
 - _009_ : Control Points > Survey Control Point**
 - _010_ : Setting Out > Rock Bolts**
 - _100_ : Position > Last Instrument Set up**
 - _110_ : Position > Angular**
 - _111_ : Measurement within Position > Angular**
 - _120_ : Position > By Coordinates**
 - _121_ : Measurement within Position > By Coordinates**
 - _130_ : Position > Resection**
 - _131_ : Measurement within Position > Resection**
- Name of the option of the program where the point has been saved:
 - _001_ : "Survey_grid"**
 - _002_ : "Survey_cross_sections"**
 - _003_ : "Survey_points"**
 - _004_ : "Check_cross_sections"**
 - _005_ : "Setting_out_front"**
 - _006_ : "Setting_out_cross_sections"**
 - _007_ : "Setting_cut_roadbed"**
 - _008_ : "Setting_out_points"**
 - _009_ : "Survey_control_points"**
 - _010_ : "Setting_out_rock_bolts"**
 - _100_ : "Instrument_setup_get_last"**
 - _110_ : "Instrument_setup_angular"**
 - _111_ : "Instrument_setup_angular"**
 - _120_ : "Instrument_setup_coordinates"**
 - _121_ : "Instrument_setup_coordinates"**
 - _130_ : "Instrument_setup_resection"**
 - _131_ : "Instrument_setup_resection"**
- Name of the standing station
- X, Y, Z coordinates of the standing station
- Scale of the standing station
- Instrument height, in meters
- Horizontal correction, in gons
- Measurement type

- 0- Reflector
- 1- Reflector sheet
- 2- Reflectorless
- 3- 360° prism

- Prism height, in meters

- Prism constant, in millimeters

- Number of the point. A dash, “-”, indicates a measurement done within position options.

- Direct measurement data:
 - Horizontal distance, in meters. The number -1000.0 indicates an invalid distance.

 - Slope distance, in meters. The number -1000.0 indicates an invalid distance.

 - Horizontal and vertical angles, in gons. The number -1000.0 indicates an invalid angle.

- Reverse measurement data:
 - Horizontal distance, in meters. The number -1000.0 indicates an invalid distance.

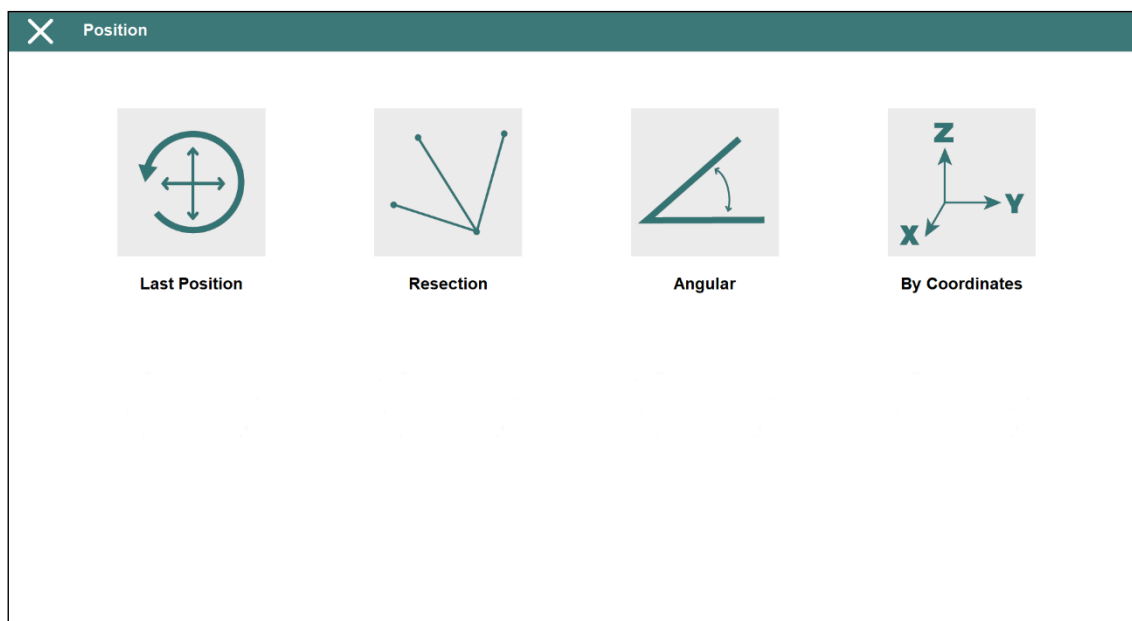
 - Slope distance, in meters. The number -1000.0 indicates an invalid distance.

 - Horizontal and vertical angles, in gons. The number -1000.0 indicates an invalid angle.

- Name of the file that stores the point. A dash, “-”, indicates a measurement done within position options.

This data can be exported to **LEA** format, compatible with **TcpMDT**. For doing this, the option **Project > Files > Exp. Raw Data** is available.

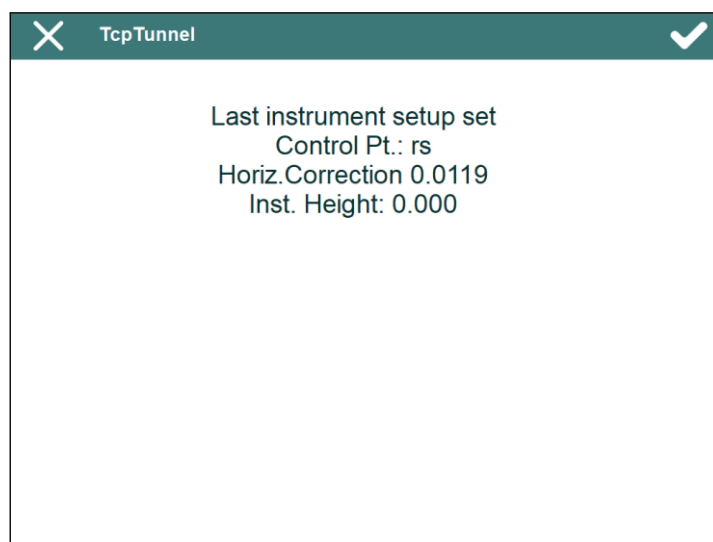
4. Positioning



4.1. Last Position

Allows one to recover the last stationing data in the application. It does not send any data to the total station.

Reports the base station used, the horizontal correction and the instrument height.



4.2. Angular

By indicating *Instrument Height*, the *Standing Station* name and an *Angle*, the station is oriented to said angle.

Should it not be possible to set the azimuth indicated at the station, information will be provided about the horizontal correction that will be applied to each observation.

4.3. By Coordinates

Instrument Height, *Prism* height and the names of the *Standing Station* and *Control Pt.* should be entered in this option.

The data outlined below is shown for each observation:

Project Data: Distance and theoretical horizontal angle between base and reference station, as well as height of reference station.

Measured Data: Distance and horizontal angle measured between the base and reference station, as well as the height measured.





Differences: Distance, horizontal angle and height differences between the theoretical and measured data. It is important to ensure that these values are reasonably small to ensure the orientation is correct.

4.4. Resection

The orientation is calculated in this option by observing two or more control points having known coordinates.

First, the name for the new standing station to be calculated and the instrument height are requested.

Then one has to indicate whether one wishes to work with **Plane** or **UTM** coordinates. In the latter case, the **UTM Zone** should be indicated.

By last, a window appears where the standing station's coordinates are calculated. This calculation is made automatically while observations are added to the **Calculation** list using the  and  buttons. Should you wish to remove any specific observation, you will have to select it in the **Calculation** list and click on . The  button deletes all of them at the same time.

Observations	Calculation	X	Y	Z
Name	N. X R. Y R.			
c1	0.0014 0.00..	675496.0556±0.00	4656312.8629±0.00	1060.4688±0.0002
c2	0.0020 0.00..			
c3	-0.0022 0.00..			

Control Pt.: rs Instr. Height: 0.000

HC 0.0154
Scl. 1.0000000
RmsX 0.0019
RmsY 0.0008
RmsZ 0.0003

>> > < << Measurement

The user must enter the accuracy parameters of the total station before make the calculation. This option is available within the menu of the title bar, y allows one to set up the values for calculating the uncertainties of the angle and distance measurements.

Horizontal Angle('') 20.000
Vertical Angle('') 20.000
Constant over Distance(mm) 5.000
Proportional to Distance(ppm) 5.000
Compensator('') 5.000

In order to add a new **Measurement**, the button carrying the same name should be clicked. In the screen that appears, one should enter the name of the control point that will be measured and do the measurement. This one can be done with reverse measurement checking the toggle within **Settings** option in the menu of the title bar.

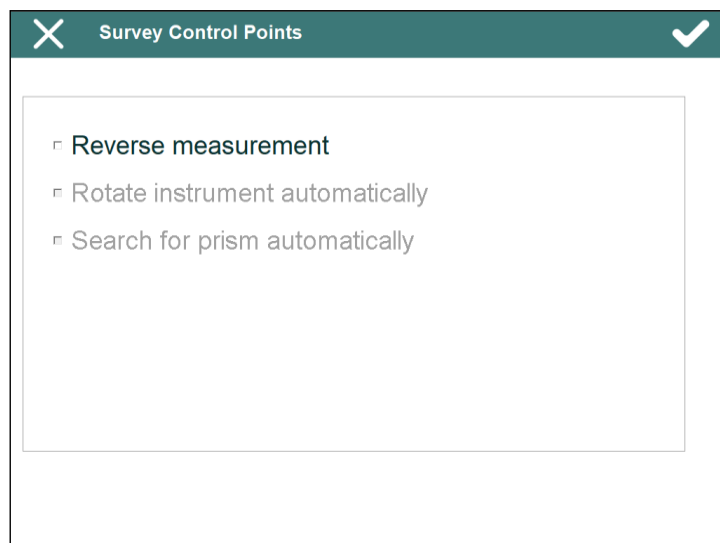
Control Pt. c1 ...

Coordinates
X 675485.544
Y 4656309.037
Z 1060.156

Measurement
HD 11.185
H 277.7627
V 101.7813

Measurement Settings

Also, with motorized total stations, the program allows to rotate automatically the total station for doing the reverse measurement and for looking for the selected control point after 2 or more control points have been measuring.



After doing a control point measurement, this one is added to **Calculation** list. The parameters will be calculated automatically if 2 or more control points have been measured.

The program shows the **X**, **Y** and **Z** coordinates, **Scale**, **Horizontal Correction** and mean square error for X (**RmsX**), Y(**RmsY**) and Z (**RmsZ**).

Finally, the program will assign the coordinates and the scale calculated to the new standing station when the accept button is clicked. The total station will then be oriented to the azimuth calculated.

A report including the following data is automatically stored in the project folder. The name of this file includes the date and the time in which it has been created.

OBSERVATIONS

Distance Observations

Stand.St.	Ctr.Pt.	Observed	Std.Dev.	Calculated	Residual
-----	-----	-----	-----	-----	-----
8	5	33.8860	0.0021	33.8856	0.0004
8	2	28.7770	0.0020	28.7765	0.0005
8	10	131.2810	0.0021	131.2811	-0.0001
8	11	78.9410	0.0021	78.9414	-0.0004

Azimuth Observations

Stand.St.	Ctr.Pt.	Observed	Horz.Corr.	Std.Dev.	Calculated	Remainder
-----	-----	-----	-----	-----	-----	-----

8	5	0.0000	142.9262	0.0011	142.9260	0.0002
8	2	87.2200	142.9262	0.0012	230.1460	0.0002
8	10	188.9020	142.9262	0.0007	331.8279	0.0002
8	11	193.6440	142.9262	0.0008	336.5700	0.0002

Angular Observations

Stand.St.	Ctr.Pt.	Ctr.Pt. 2	Observed	Std.Dev.	Calculated	Remainder
-----	-----	-----	-----	-----	-----	-----
8	5	2	87.2200	0.0011	87.2200	-0.0000
8	5	10	188.9020	0.0008	188.9020	0.0000
8	5	11	193.6440	0.0009	193.6440	-0.0000
8	2	10	101.6820	0.0008	101.6819	0.0001
8	2	11	106.4240	0.0009	106.4240	-0.0000
8	10	11	4.7420	0.0008	4.7421	-0.0001

Vertical Observations

Stand.St.	Ctr.Pt.	Observed	Std.Dev.	Calculated	Remainder
-----	-----	-----	-----	-----	-----
8	5	2.9969	0.0021	2.9964	0.0005
8	2	-0.1844	0.0020	-0.1846	0.0003
8	10	-5.0565	0.0021	-5.0556	-0.0009
8	11	-3.4036	0.0021	-3.4036	0.0001

COMBINATIONS

E1	E2	E3	X Coord.	Y Coord.	XY Error
-----	-----	-----	-----	-----	-----
5	2	10	1000.0000	1000.0000	0.0014
5	2	11	1000.0000	1000.0000	0.0013
5	10	11	1000.0044	999.9967	0.0042
2	10	11	1000.0001	1000.0003	0.0015

Average X= 1000.0011 Average Y = 999.9992 Average Error = 0.0021

CONTROL POINTS

Ctr.Pt.	X Coord.	Y Coord.	Z Coord.	Ang. Error	Dist. Error	Height Error
-----	-----	-----	-----	-----	-----	-----
5	1026.4700	978.8440	102.9970	0.0002	0.0004	0.0005
2	986.8770	974.3900	99.8160	0.0002	0.0005	0.0003
10	884.7870	1062.9340	94.9450	0.0002	-0.0001	-0.0009

11 933.7290 1042.8940 96.5970 0.0002 -0.0004 0.0001

RESULTS

Planimetric Adjustment

Solution: X = 1000.0000 X = 1000.0000 HC = 142.9260

Standard deviation of parameters: X = 0.0000 Y = 0.0000

Altimetric Adjustment

Solution: Z = 100.0006

Standard deviation of parameter: Z = 0.0003

Observation Equations

Each observation making up a resection can generate several equations among of the following:

Distance equations

Azimuth equation

Angle equation

Vertical equation.

Each equation is determined from an observation's data or from the relationship between two observations, as is the case with angle equations. The program determines which of the equations can be generated based on the data available. For instance, if an observation is just of distance, only such an equation will be created. If the observation is angular, the angle and azimuth equations will be created. In this way, better use is made of the data gathered.

Each equation affects the coefficient, residual and weighting matrices. The values of the A coefficient matrix depend on the type of equation and are based on linearization using Taylor series non-linear equations generated by the observations.

The L vector residual values are calculated by simply finding the difference between the observed and calculated values for each observation. This coincides with the data displayed in the program's information windows.

$$L_i = V_o - V_c$$

where:

L_i = Residue

V_o = Observed value

V_c = Calculated value

Finally, the diagonal matrix P for weightings contains a factor which affects each equation and determines its fitness or precision.

Measurement uncertainties

Measurement uncertainty is a parameter associated with the result of a measurement which characterize the dispersion of values which could reasonably be attributed to the measurand. The less uncertainty about the measurement, the better.

There are two types of uncertainty:

Angle measurement uncertainty.

Distance measurement uncertainty.

Angle measurement uncertainty

ISO Standard 17123-3 sets out the procedure to be followed by a user to determine and evaluate the angle measurement uncertainty of the instrument used. Although the quality of the instrument measurement depends on various factors such as offset uncertainty, the angle resolution of the instrument, telescope magnification etc., ISO Standard 17123-3 does to set out to study each of these factors, but rather to ascertain the final effect produced by them all, evaluation the typical deviation of the measurement.

The expression of the combined typical uncertainty of an angle can be evaluated as:

$$\sigma_{\alpha} = \pm \sqrt{\sigma_{\alpha_{ISO}}^2 + \sigma_{\alpha_o}^2 + \sigma_{\alpha_c}^2 + \sigma_{\alpha_j}^2 + \sigma_{\alpha_{comp}}^2}$$

Angle measurement contribution of the station

Pursuant to ISO standard 17123-3, the typical horizontal and vertical angle measurement uncertainty with a theodolite is expressed by means of the typical experimental deviation of the mean of a horizontal angle direction (σ_{ISO-HZ}) and of the mean of a vertical angle (σ_{ISO-V}). Hence, for a given angle direction the typical deviation of the measurement encompassing the traditional “accidental reading and aiming errors” will be:

$$\begin{aligned} \sigma_{\alpha_{ISO}} &= \pm \sigma_{HZ} \sqrt{2} & \sigma_{HZ} &= \pm \sigma_{ISO-HZ} \sqrt{2} \\ \sigma_{\alpha_{ISO}} &= \pm \sigma_V \sqrt{2} & \sigma_V &= \pm \sigma_{ISO-V} \sqrt{2} \end{aligned}$$

The measurement contribution of horizontal angles will be used in the event of typical experimental deviation of the mean of a horizontal angle direction. In the same way as for vertical angles.

Contribution through stake centering

One of the sources of uncertainty in an angular or distance measurement occurs when the target sign is not perfectly centered. Its contribution to the uncertainty of the horizontal angle is:

$$\sigma_{\alpha_o} = \frac{\sigma_o}{D} \rho$$

where:

D = Distance measured.

ρ = Hundredths of seconds which have a radian: An approximation of this value is: 636619,772.

$$\sigma_o = \frac{U_o}{3.5}$$

where:

U_o = a value of 0.75 mm has been assumed as this is the most appropriate value for current stations with optical or laser plummet.

It is divided by 3.5 to achieve a coverage probability of 99.7%

Contribution through instrument centering

One of the sources of uncertainty in an angular or distance measurement occurs when the total station is not perfectly centered at the station point. Its contribution to the uncertainty of the horizontal angle is:

$$\sigma_{\alpha_c} = \frac{\sigma_c}{D} \rho$$

where:

D = Distance measured.

ρ = Hundredths of seconds which have a radian: An approximation of this value is: 636619,772.

$$\sigma_c = \frac{U_c}{3.5}$$

where:

U_c = a value of 0.75 mm has been assumed as this is the most appropriate value for current stations with optical or laser plummet.

It is divided by 3.5 to achieve a coverage probability of 99.7%

Contribution through stake inclination

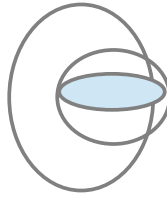
One of the sources of uncertainty when a total station is observed directly at the center of the prism, when measuring a horizontal angle or the geometric distance, is its lack of verticality compared with the point on which it has stopped. Its contribution to the uncertainty of the horizontal angle is:

$$\sigma_j = \frac{m(\max \beta')}{3.5}$$

where:

m = Prism height.

β = Inclination angle of the target sign on the vertical; for its simplification, the value of 3' has been assumed as the most likely maximum inclination we are going to have. This would correspond to the position where the bubble would be at a tangent to the circumference drawn:



It is divided by 3.5 to achieve a coverage probability of 99.7%

$$\sigma_{\alpha_j} = \frac{\sigma_j}{D} \rho$$

where:

D = Distance measured.

ρ = Hundredths of seconds which have a radian: An approximation of this value is: 636619,772.

Contribution through compensator accuracy

$$\sigma_{\alpha_{comp}} = \frac{\sigma_{comp}}{12}$$

where:

σ_{comp} = Compensator accuracy in hundredths of seconds.

Distance measurement uncertainty

ISO Standard 17123-4 sets out the procedure to be followed to determine and the measurement uncertainty of a distance meter. Under this standard a simplified or complete procedure can be carried out in line with the needs of the user. As with ISO standard 17123-3, ISO standard 17123-4 seeks to ascertain the final effect caused by all the factors which contribute to determining the distance measurement uncertainty, evaluating the typical deviation of the measurement.

The expression of the combined typical uncertainty of distance can be evaluated as:

$$\sigma_{Dg} = \pm \sqrt{\sigma_{ISO-EDM}^2 + \sigma_o^2 + \sigma_c^2 + \sigma_j^2}$$

where:

$\sigma_{ISO-EDM}$ = Contribution by measurement of the geometric distance using electromagnetic methods.

Manufacturers usually present the uncertainty of their equipment by means of a constant part plus a part proportional to the distance measured $\pm (a \text{ mm} + b \text{ ppm} \cdot D)$, which is a way of indicating the typical deviation for any distance. If the evaluation carried out by the manufacturer is used, appropriately applying the propagation of uncertainties, the typical measurement uncertainty ($\sigma_{ISO-EDM}$) obtained when measuring a given distance D , it can be evaluated by means of:

$$\sigma_{ISO-EDM} = \pm \sqrt{a[m]^2 + (b \text{ ppm} \cdot 10^{-6} D[m])^2}$$

where:

a = Constant part for the distance measured.

b = Proportional part for the distance measured.

D = Distance measured.

σ_o , σ_c , σ_j will be the same as those used in the combined typical uncertainty of angles

$$\sigma_o = \frac{U_o}{3.5} \quad \sigma_c = \frac{U_c}{3.5} \quad \sigma_j = \frac{m(\max \beta^{rad})}{3.5}$$

Slope measurement uncertainty

The expression of the combined typical uncertainty of a change in level can be evaluated as:

$$\sigma_{\Delta Z} = \pm \sqrt{\sigma_{ISO-EDM}^2 + \sigma_o^2 + \sigma_c^2 + \sigma_j^2}$$

$\sigma_{ISO-EDM}$, σ_o , σ_c , σ_j will be the same as those used in the combined typical uncertainty of distances

$$\sigma_{ISO-EDM} = \pm \sqrt{a[m]^2 + (b \text{ ppm} \cdot 10^{-6} D[m])^2}$$

$$\sigma_o = \frac{U_o}{3.5} \quad \sigma_c = \frac{U_c}{3.5} \quad \sigma_j = \frac{m(\max \beta^{rad})}{3.5}$$

Hence, with the minimum square adjustment by observation equations, to construct the weight matrix P , for each value the inverse of the square of the typical deviation would be introduced in each case whether they are angle or distance measurements.

$$P_i = \frac{1}{\sigma_i^2}$$

The standard deviation values are affected by the equipment configuration.

García Balboa, J. L. ,Ruiz Armenteros, A. M. & Mesa Mingorance, J. L. (2011). Evaluation of the measurement uncertainty of angles, distances and changes in level measured with topographic instrumentation. Mapping 149, 6-27.

Distance Equation

Distance type observations have the following information: source and target stations, distance observed, standard deviation and residue. The general formula is:

$$\frac{x_{i0} - x_{j0}}{IJ_0} dx_i + \frac{y_{i0} - y_{j0}}{IJ_0} dy_i + \frac{x_{j0} - x_{i0}}{IJ_0} dx_j + \frac{y_{j0} - y_{i0}}{IJ_0} dy_j = k_{l_{ij}} + v_{l_{ij}}$$

where:

$$k_{l_{ij}} = l_{ij} - IJ_0$$

$$IJ_0 = \sqrt{(x_{j0} - x_{i0})^2 + (y_{j0} - y_{i0})^2}$$

Azimuth Equation

Azimuth observations consist of source and target stations, observed azimuth, calculated azimuth, standard deviation and residue. The general formula is:

$$\frac{y_{i0} - y_{j0}}{(IJ_0)^2} dx_i + \frac{x_{i0} - x_{j0}}{(IJ_0)^2} dy_i + \frac{y_{j0} - y_{i0}}{(IJ_0)^2} dx_j + \frac{x_{j0} - x_{i0}}{(IJ_0)^2} dy_j = k_{l_{ij}} + v_{az_{ij}}$$

where:

$$k_{az_{ij}} = Az_{ij} - \tan^{-1} \left(\frac{x_{j0} - x_{i0}}{y_{j0} - y_{i0}} \right) + C$$

$$(IJ_0)^2 = (x_{j0} - x_{i0})^2 + (y_{j0} - y_{i0})^2$$

Angular Equation

Angular observations consist of source and target stations, observed angle, calculated angle, standard deviation and residue. The general formula is:

$$\begin{aligned} & \frac{y_{i0} - y_{b0}}{(IB_0)^2} dx_b + \frac{x_{b0} - x_{i0}}{(IB_0)^2} dy_b + \left(\frac{y_{b0} - y_{i0}}{(IB_0)^2} - \frac{y_{f0} - y_{i0}}{(IF_0)^2} \right) dx_i \\ & + \left(\frac{x_{i0} - x_{b0}}{(IB_0)^2} - \frac{x_{i0} - x_{f0}}{(IF_0)^2} \right) dy_i + \frac{y_{f0} - y_{i0}}{(IF_0)^2} dx_f + \frac{x_{i0} - x_{f0}}{(IF_0)^2} dy_f \\ & = k_{\theta_{if}} + v_{\theta_{if}} \end{aligned}$$

where:

I = current station

B = previous station

F = next station

$$k_{\theta_{bif}} = \theta_{bif} - \theta_{bif_0}$$

$$\theta_{bif_0} = \tan^{-1} \left(\frac{x_{f_0} - x_{i_0}}{y_{f_0} - y_{i_0}} \right) - \tan^{-1} \left(\frac{x_{b_0} - x_{i_0}}{y_{b_0} - y_{i_0}} \right) + D$$

$$(IB_0)^2 = (x_{b_0} - x_{i_0})^2 + (y_{b_0} - y_{i_0})^2$$

$$(IF_0)^2 = (x_{f_0} - x_{i_0})^2 + (y_{f_0} - y_{i_0})^2$$

Vertical equation

Vertical observations indicate the differences between the slope observed and calculated. The general formula is:

$$dz_i - dz_j = k_{d_{ij}} + v_{d_{ij}}$$

where:

$$k_{d_{ij}} = h_{ij} - (z_{i_0} - z_{j_0})$$

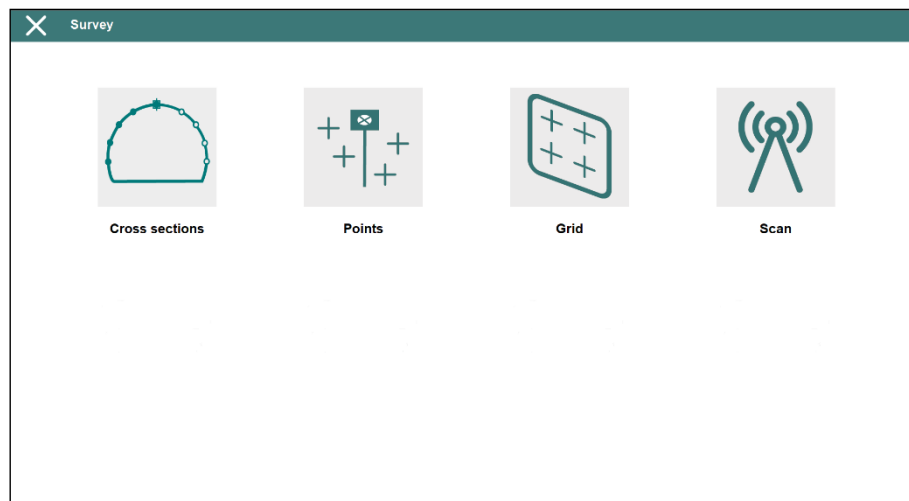
García Balboa, J. L., Ruiz Armenteros, A. M. & Mesa Mingorance, J. L. (2011). *Evaluation of the measurement uncertainty of angles, distances and changes in level measured with topographic instrumentation. Mapping 149*, 6-27. (http://coello.ujaen.es/publicaciones/Garcia-Ruiz-Mesa_2011_Mapping_Evaluacion_incertidumbre.pdf, last access: August 2013)

García-Asenjo, L., Hernández, D. & Llácer, C. (2004). *Study about the influence of geodesic corrections on topographic works carried out as from classical measurements and GPS. 8th National Topography and Mapping Congress TOPCART2004.*

Wolf, P.R. & Ghilani, C.D. (1996). *Adjustment computations: statistic and least squares in surveying and GIS.*

Brinker, R. C. & Minnick, R. (1995). *The Surveying Handbook.*


5. Surveying




5.1. Cross-Section

Allows one to measure tunnel cross sections within the station range indicated. In order to do so, the following data is requested:

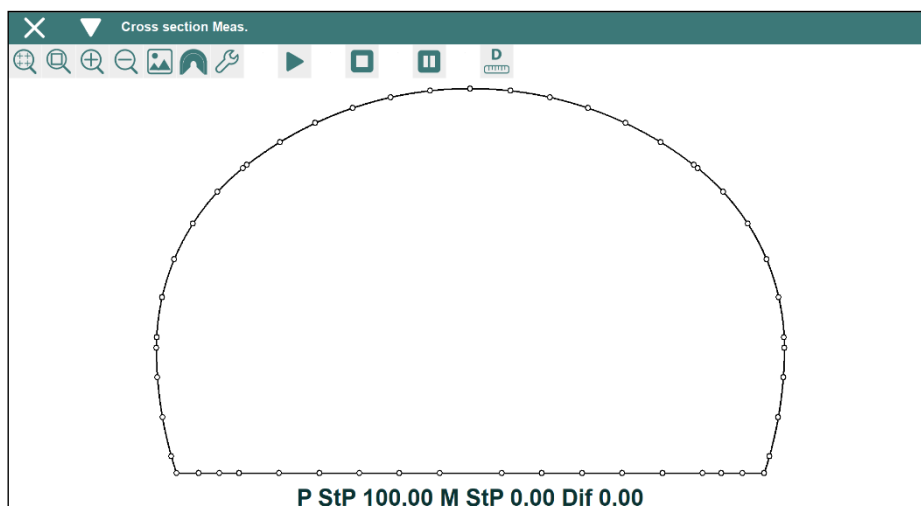
The image shows a dialog box titled 'Cross section Meas.' with a close button (X), a help button (?), and a confirm button (checkmark) in the top right corner. Inside the dialog, there is a section labeled 'Cross section Points' with a settings icon (wrench) to its right. Below this, there are three input fields with labels to their left: 'Initial Sta.' with a value of '100.0' and a '<' button; 'Final Sta.' with a value of '110.0' and a '<' button; and 'Sta. Interval' with a value of '2.0'.

Initial Station: The station can be measured by clicking the  button.

Final Station: The station can be measured by clicking the  button.

Station Interval: Station increment value.

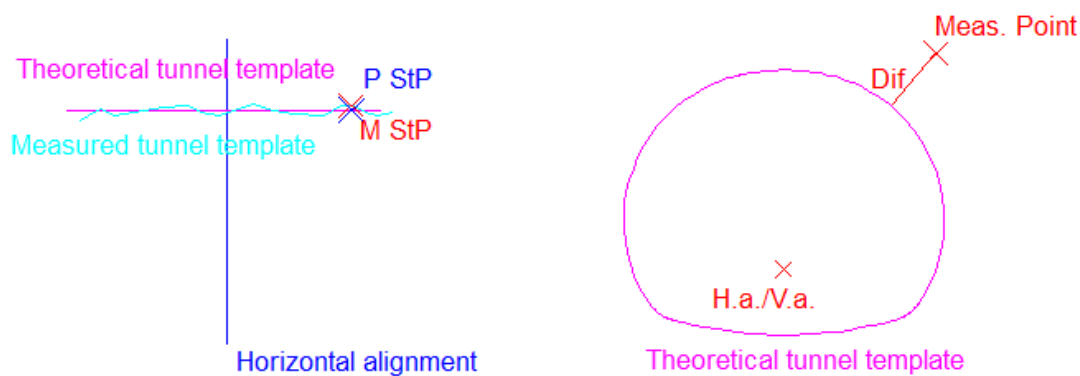
After setting up the theoretical points (see **Features and Functionality > [Theoretical Points of the Tunnel Template](#)**) and entering the required data the following screen is shown:



P StP: Theoretical station of the cross section (or profile).

M StP: Measured station of the cross section (or profile).

Dif: Difference between tunnel template and measured point.



Change between top and front view.



Show graphically the differences between tunnel template and measured cross section.



Change total station settings.



Start the survey.



Stop the survey.

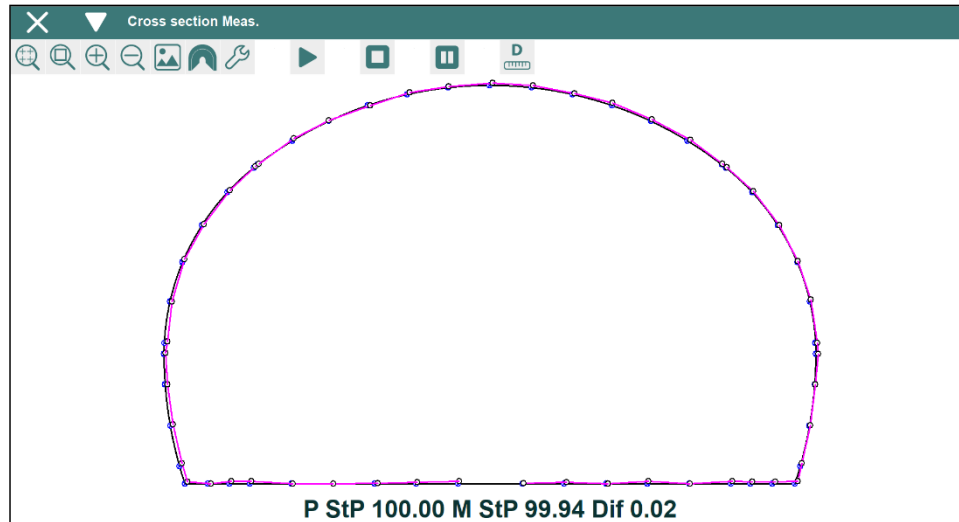


Pause the survey.

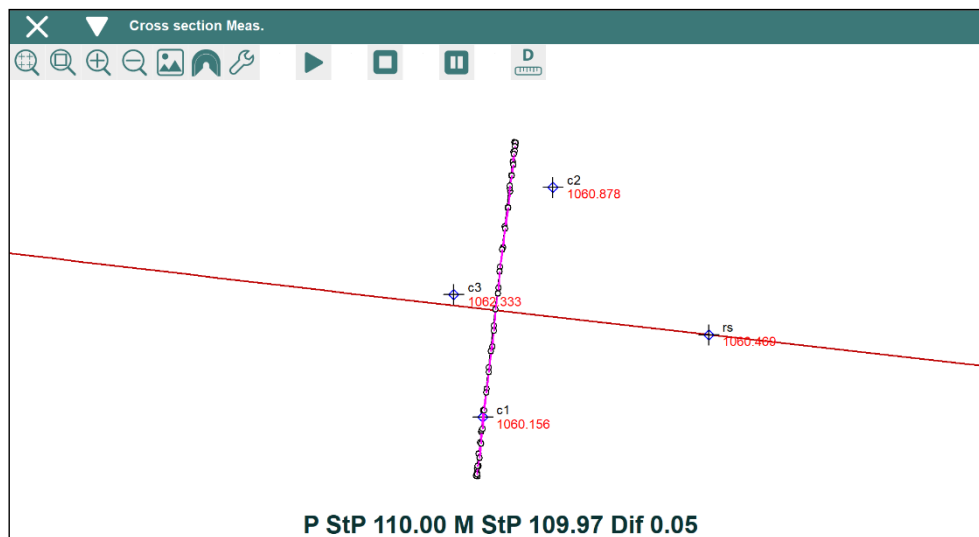


Start area and distance calculations.

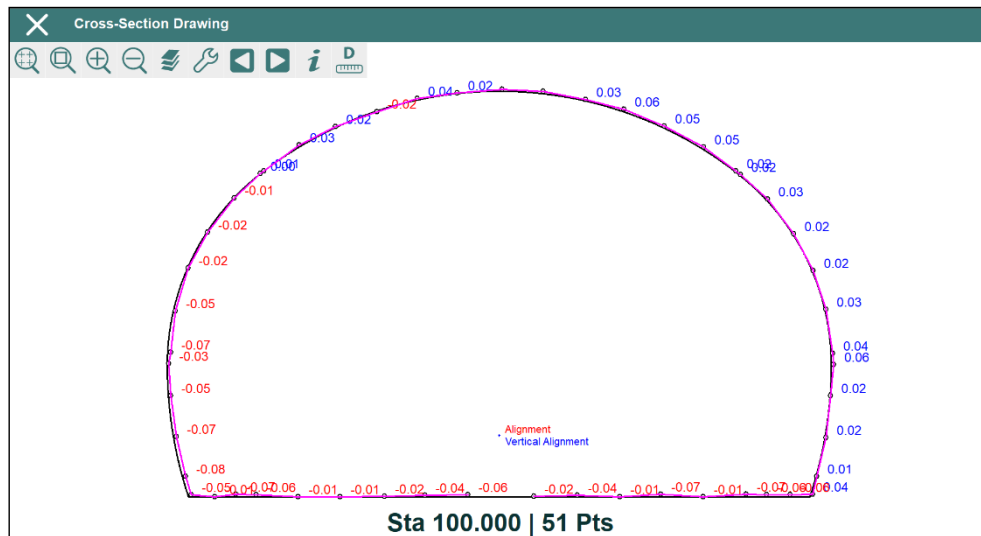
After clicking the start button, the program will try to find, for each station, the theoretical points by using the station tolerance and the number of iterations entered in settings option. For each measured point, the program shows the theoretical and measured stations and the difference regard with the tunnel template. The stored points will be drawn in blue color and the remaining ones in red color.



The program allows one to change between top and front views using the button 



After survey finalized, a graphic with theoretical and measured cross sections is shown.



Before starting survey, several setting parameters can be modified through the option included in the menu of the title bar. Apart from the mentioned parameters, station tolerance and number of iterations, messages related measurement errors and points out of tolerance can be disabled.

The 'Survey' window contains the following settings:

- ☐ Save Points Automatically
- ☐ Ignore Measurement Errors
- ☐ Ignore Points Out of Tolerance
- ☐ Remember Last Location
- Iterations:
- ☐ Limit Chainage Analysis
- Maximum Differences:

Left of HA	<input type="text" value="10.000"/>	Right of HA	<input type="text" value="10.000"/>
Above VA	<input type="text" value="10.000"/>	Below VA	<input type="text" value="10.000"/>

The 'Tolerances' window contains the following settings:

Longitudinal	<input type="text" value="0.001"/>
Transverse	<input type="text" value="0.001"/>
Vertical	<input type="text" value="0.001"/>
Station	<input type="text" value="0.100"/>
3D Distance	<input type="text" value="0.100"/>

If a measurement error occurs, the following screen is shown, which allows one to **Retry** or **Continue**, go to **Next Point** or **Cancel** the process.

5.2. Points


This option allows one to do point measurements manually.

The 'Point Measurements' window contains the following fields and controls:

- Number:
- Code:
- SD:
- HD:
- H:
- V:
- X:
- Y:
- Z:
- Z Dif:
- Navigation icons: Back, Forward, Home, Search, Save, Print, Settings, Close.

The **Number** of the point (alphanumeric) must be entered and, optionally, the **Code**, which can be selected from the program's database.

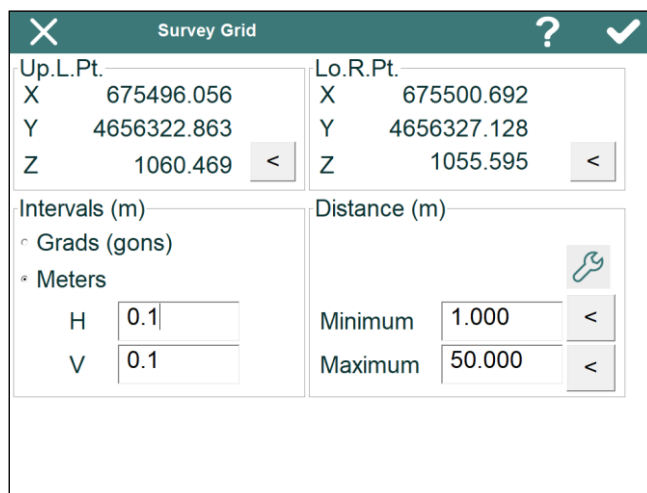
For each observation the program displays the geometric distance (**SD**), the horizontal or reduced distance (**HD**), the horizontal (**H**) and vertical (**V**) angles, the **X**, **Y**, **Z** coordinates and the height difference (**Z Dif**) between measured point and standing station.

The point will not be stored until the  button is pressed or automatically if this option has been set in configuration. In addition to the information in the points file, the program stores the raw observation data in the current survey file.

The  button allows one to access the data of the current points file.

5.3. Grid

This option allows one to automatically measure a point grid. Two points should be measured, upper left point and lower right point. Additionally, the intervals in horizontal and vertical as well as the minimum and maximum distances within which an observed point is considered as valid must be indicated.



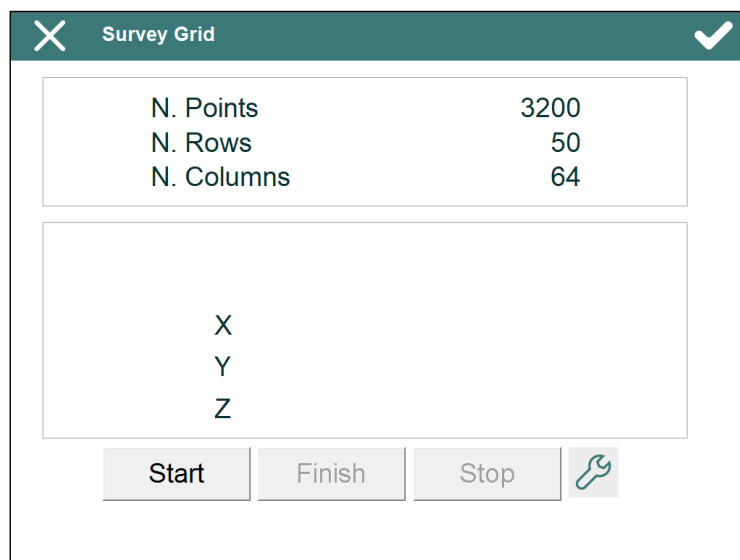
Up.L.Pt.		Lo.R.Pt.	
X	675496.056	X	675500.692
Y	4656322.863	Y	4656327.128
Z	1060.469 <	Z	1055.595 <

Intervals (m)		Distance (m)	
<input type="radio"/> Grads (gons) <input checked="" type="radio"/> Meters		<input type="button" value="⚙️"/>	
H	0.1	Minimum	1.000 <
V	0.1	Maximum	50.000 <

The total number of points (**N.Points**) making up the grid, as well as the number of rows (**N.Rows**) and columns (**N.Columns**) are shown in the data gathering screen.

Information of the corresponding point number (**Pt**), number of saved points, horizontal and vertical angles and **X**, **Y**, **Z** coordinates is shown for each point observed.

The process can be finished or stopped at any moment.



The 'Survey Grid' dialog box has a title bar with a close button (X) and a checkmark button. It contains a table with the following data:

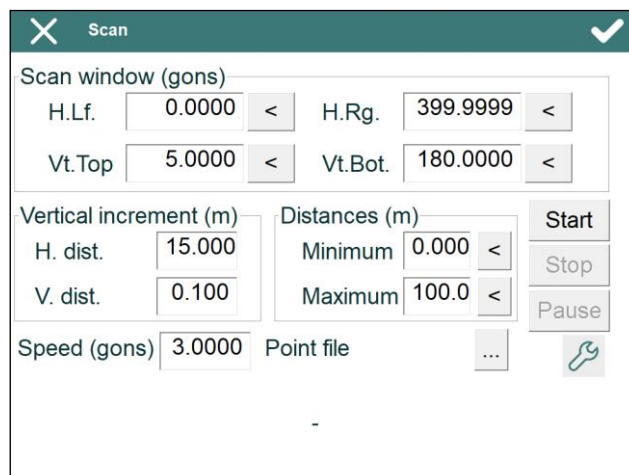
N. Points	3200
N. Rows	50
N. Columns	64

Below the table is a large empty rectangular area. At the bottom, there are four buttons: 'Start', 'Finish', 'Stop', and a gear icon.

5.4. Scan

This option is only available for total stations that allows scan mode. It's similar to **Grid** function but the total station is measuring points while it's turning.

The requested data are the following:



The 'Scan' dialog box has a title bar with a close button (X) and a checkmark button. It contains several input fields and buttons:

- Scan window (gons):**
 - H.Lf. 0.0000 <
 - H.Rg. 399.9999 <
 - Vt.Top 5.0000 <
 - Vt.Bot. 180.0000 <
- Vertical increment (m):**
 - H. dist. 15.000
 - V. dist. 0.100
- Distances (m):**
 - Minimum 0.000 <
 - Maximum 100.0 <
- Speed (gons):** 3.0000
- Point file:** ...
- Buttons:** Start, Stop, Pause, and a gear icon.

H.Lf.: Horizontal angle of the top-left corner.

Vt.Top: Vertical angle of the top-left corner.

H.Rg.: Horizontal angle of the bottom-right corner.

Vt.Bot.: Vertical angle of the bottom-right corner.

Vertical increment (m): Horizontal (**H. dist.**) and vertical increments (**V. dist.**) to calculate the vertical angle increment.

Distances: Minimum and maximum distances within which the point is stored.

Speed (gons): Speed rotation of the total station in gons.

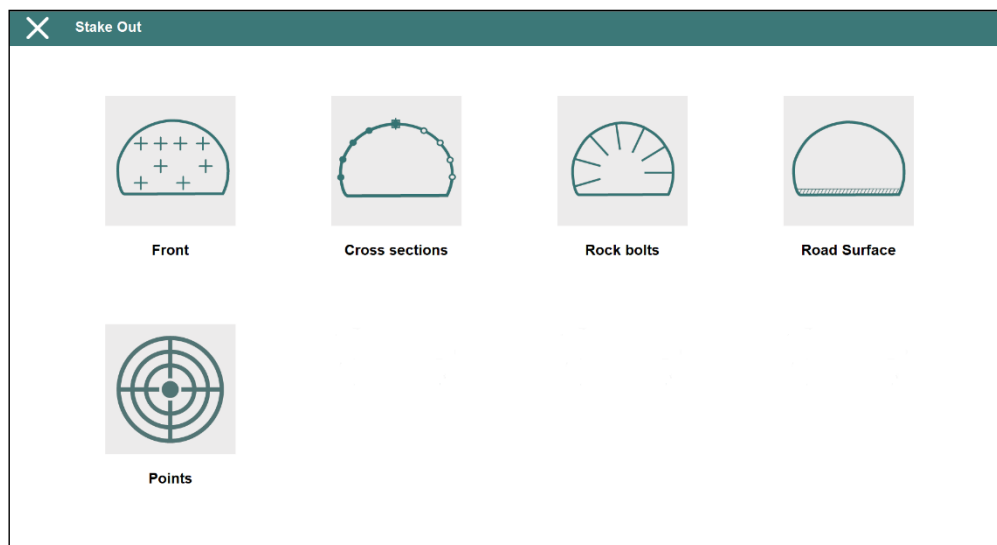
Point file: Name of the point file to store the measured points.

Start: Start the scan.

Stop: Stop the scan.

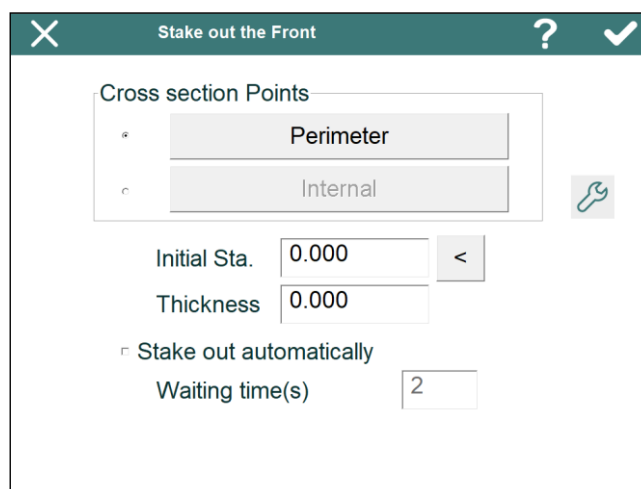
Pause: Pause the scan.

6. Stake out



6.1. Front

Allows one set out the points marking the tunnel cross-section's excavation front.



The user can select points on the tunnel template (*Perimeter*), or inside it (*Internal*). In the first case, there are several methods (see **Features and Functionality > [Theoretical Points of the Tunnel Template](#)**).

✕

Cross section Points

✓

Method

Length (meters)

Interval

1.000

Initial Value

<

Final Value



<

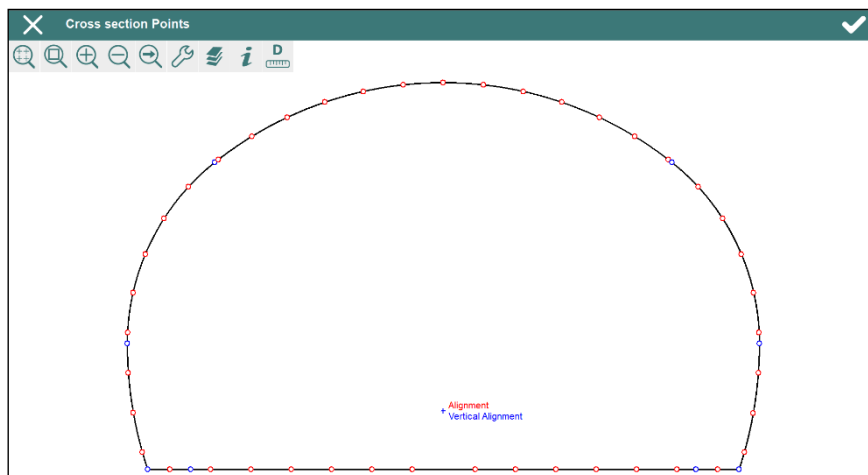
Include Keystone

Unique Points

Include Road Surface

Exclusions



On the other hand, the program allows one to define theoretical points by entering a horizontal and vertical offsets regard to horizontal and vertical alignment application points. These points can be entered manually or import them from file. Each line in the file must have the format: **number h_offset v_offset**. A blank space must be entered between fields.

Internal Points

Number	H Offset	V Offset
1	-5.948	0.934
2	-5.317	2.537
3	-3.935	2.537
4	-2.552	2.537
5	-2.552	1.804
6	-5.317	1.804

Number

1

H Offset

0.000

V Offset


0.000

Insert

Delete

Import

Export



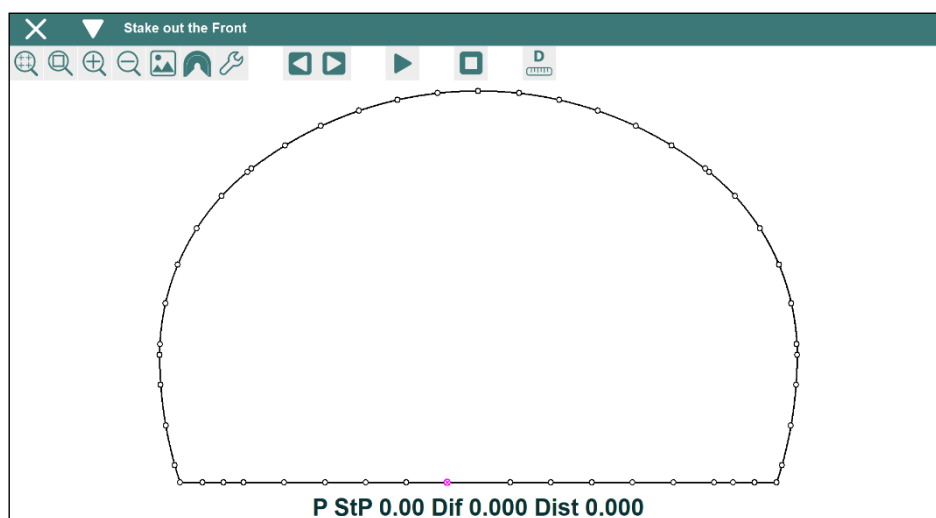
In both cases following input data is requested:

Initial Station. Approximate station of the excavation front. The tunnel template will be created in this station for comparing with measured points.

Thickness: It allows to create parallel tunnel templates. If a positive value is entered, the program will create a tunnel template with a bigger radius and, otherwise, a smaller tunnel template will be created.

If you want to stake out in continuous mode, the check box **Stake out automatically** must be enabled. In this case, a **Waiting time**, in seconds, must be entered for stopping the process after each point is staked out.

Once theoretical data is entered, clicking on accept button, the program shows the graphic screen for staking out.



P StP: Theoretical station of the cross section (or profile).

Dif: Difference between tunnel template and measured point.

Dist: 3D distance between theoretical and measured point.



Change between top and front view.



Show graphically the differences between tunnel template and measured cross section.



Change total station settings.



Go to the previous point to stake out.



Go to the next point to stake out.



Start the stake out of the current point.



Stop the stake out of the cross section.



Start area and distance calculations.

After finishing the setting out of the point, it will be drawn in blue color if it meets the tolerances and it has been stored in result file, otherwise it will be drawn in red.

Before starting the setting out, several parameters can be modified within the setting option, such as [3D Distance](#) and the number of [Iterations](#).

Survey

- ☐ Save Points Automatically
- ☐ Ignore Measurement Errors
- ☐ Ignore Points Out of Tolerance
- ☐ Remember Last Location
- Iterations
- ☐ Limit Chainage Analysis

Maximum Differences

Left of HA	10.000	Right of HA	10.000
Above VA	10.000	Below VA	10.000

Tolerances

Longitudinal	0.001
Transverse	0.001
Vertical	0.001
Station	0.100
3D Distance	0.100

6.2. Cross Sections

This option allows one to set out individual points of the profiles within the range between the initial and final station.

Stak out Cross sections

Cross section Points ⚙️

Initial Sta.	<input type="text" value="100.0"/>	<	
Final Sta.	<input type="text" value="110.0"/>	<	
Sta. Interval	<input type="text" value="0.000"/>		
Thickness	<input type="text" value="0.000"/>		
Max. Dif.	<input type="text" value="0.100"/>		

The following data is requested:

Cross section Points: Allows user to set the theoretical points of the tunnel template (see **Features and Functionality** > [Theoretical Points of the Tunnel Template](#)).

Initial Station

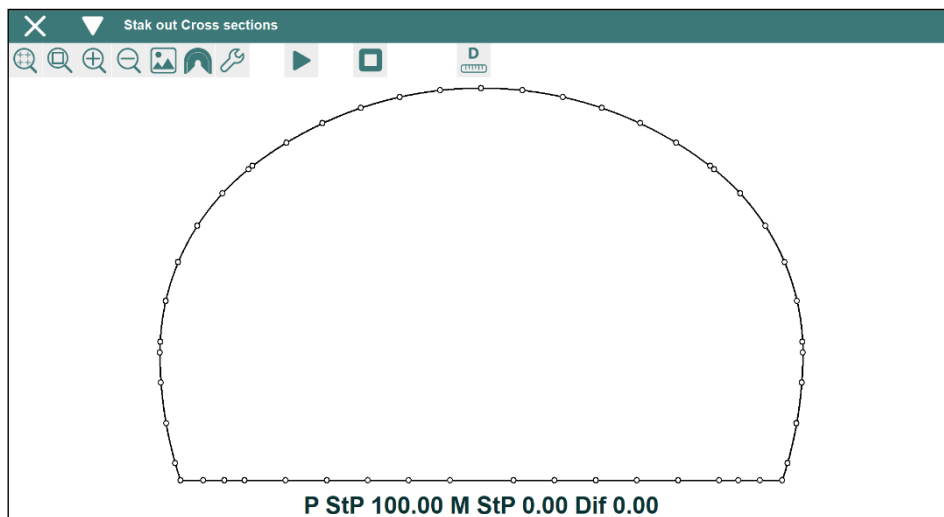
Final Station

Station Interval: Station increment value.

Thickness: Allows one to create tunnel templates that are parallel to the tunnel template. A positive thickness will create a tunnel template with a larger radius and a negative thickness will create one with a smaller radius.

Max. Dif. (maximum difference): Filter which serves to discard points having a displacement perpendicular to the cross-section that is greater than the value indicated.

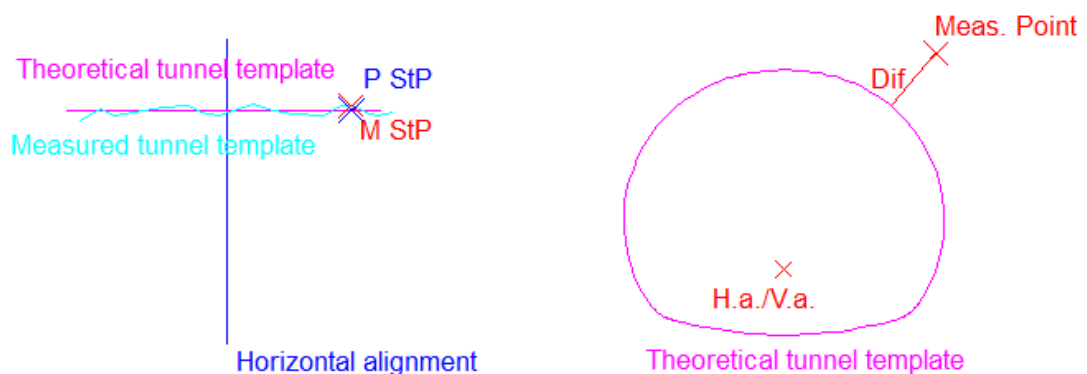
After setting up the theoretical points and entering the required data the following screen is shown:



P StP: Theoretical station of the cross section (or profile).

M StP: Measured station of the cross section (or profile).

Dif: Difference between tunnel template and measured point.



Change between top and front view.



Show graphically the differences between tunnel template and measured cross section.



Change total station settings.



Start the stake out of the current point.



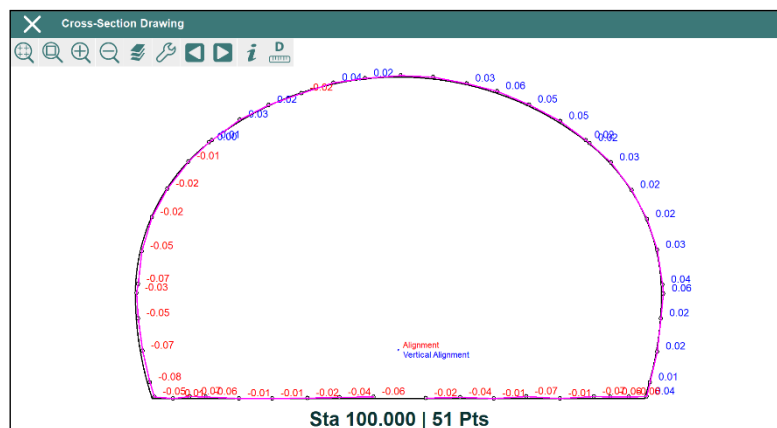
Stop the stake out of the cross section.



Start area and distance calculations.

The points are staken out one by one so, the start button must be clicked for each point. The point will be drawn in blue if the tolerances are rights and it's stored in the result file, otherwise, the point is drawn in red. If the stop button is clicked, the program will start again with the first point of the first cross section.

After survey finalized, a graphic with theoretical and measured cross sections is shown.



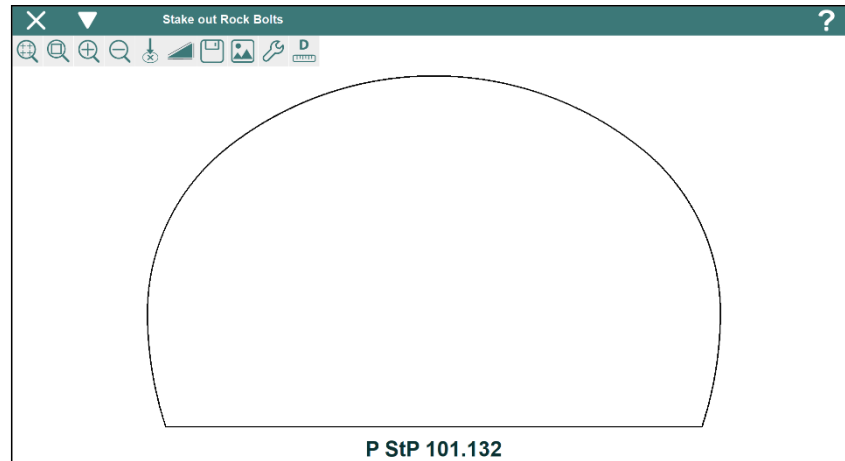
Before starting survey, several setting parameters can be modified through the option included in the menu of the title bar. Apart from the mentioned parameters, station tolerance and number of iterations, messages related measurement errors and points out of tolerance can be disabled.

Survey			
<input type="checkbox"/>	Save Points Automatically		
<input type="checkbox"/>	Ignore Measurement Errors		
<input type="checkbox"/>	Ignore Points Out of Tolerance		
<input type="checkbox"/>	Remember Last Location		
Iterations	<input type="text" value="3"/>		
<input type="checkbox"/>	Limit Chainage Analysis		
Maximum Differences			
Left of HA	<input type="text" value="10.000"/>	Right of HA	<input type="text" value="10.000"/>
Above VA	<input type="text" value="10.000"/>	Below VA	<input type="text" value="10.000"/>



Tolerances	
Longitudinal	<input type="text" value="0.001"/>
Transverse	<input type="text" value="0.001"/>
Vertical	<input type="text" value="0.001"/>
Station	<input type="text" value="0.100"/>
3D Distance	<input type="text" value="0.100"/>

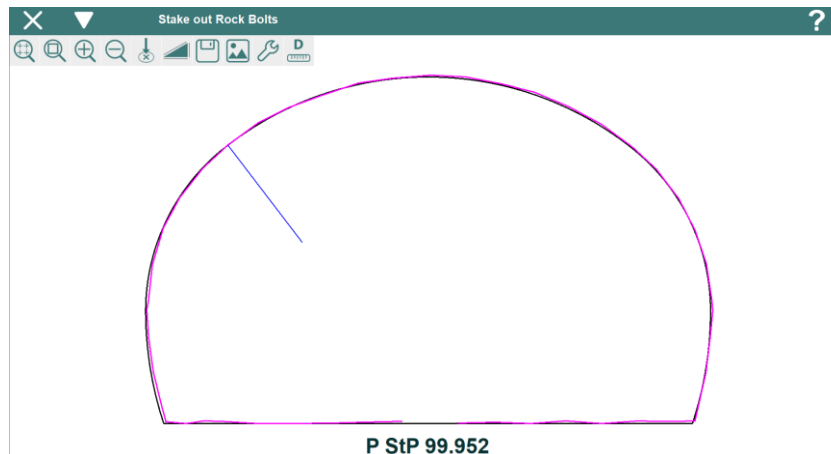
6.3. Rock Bolts

This feature makes easy the positioning of bolts for supporting rock or concrete, giving instructions to operator for the right placement on the desired station besides being perpendicular to template.

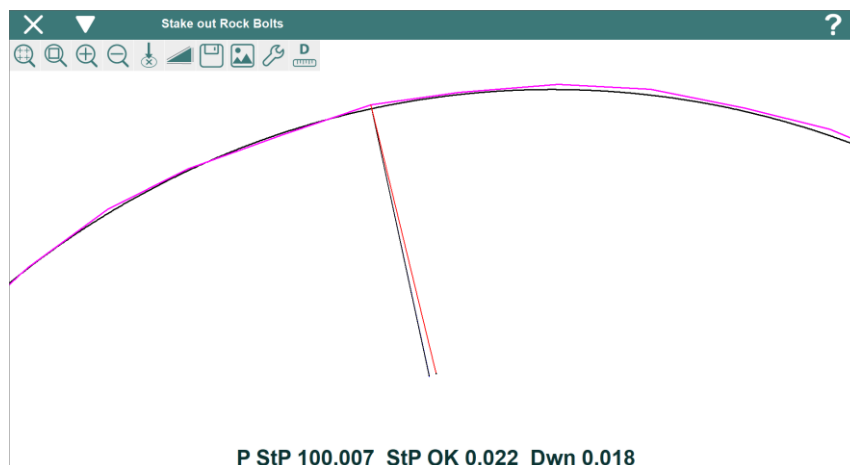


For each theoretical station, the program shows the tunnel template that has been assigned to that station and the measured profile if the point file contains points within the tolerance. The first drawing is the tunnel template assigned to the initial station of the horizontal alignment.

Once located the theoretical point for drilling,  button must be clicked and, then, do a measurement with the button . The program will show the theoretical station calculated and it will draw, in blue color, the theoretical position of the rock bolt.



The following measurements must be done pointing to a guide. The objective is to position this guide online with the calculated station and perpendicular to tunnel template. For doing this, the program shows the movements to do forward (**Fwd**) and backward (**Bwd**), to reach the station (**StP OK**), and up (**Up**) and down (**Dwn**), to reach the position of the bolt.




For each measurement, the program draws, in black color, the theoretical position, and, in red color, the measured one.

The [Vertical](#) and [Station](#) tolerances, within the setting screen, set up, respectively, when the height and station are valid.

The screenshot shows a "Tolerances" window with a table of settings:

Tolerance Type	Value
Longitudinal	0.001
Transverse	0.001
Vertical	0.001
Station	0.100
3D Distance	0.100


If  button is clicked on, the last measured point will be stored in the result file and the drawing will be initialized with the last calculated station.

6.4. Points

Allows one to set out one or more points of any points file.

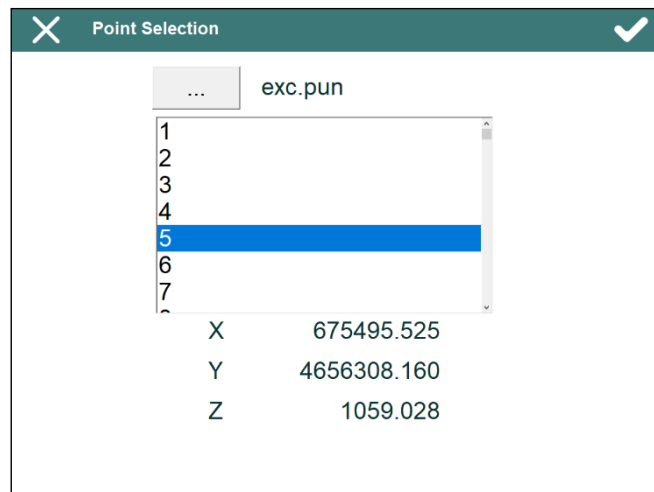
The screenshot shows a "Stake out Points" window with the following settings:

- Individual: 1
- Manual: ...
- Code: ...
- Graphic: ...
- Interval:
 - Initial Pt: 1
 - Final Pt: 2970
 - Interval: 1
- Control Pt: ...
- Current File: exc.pun

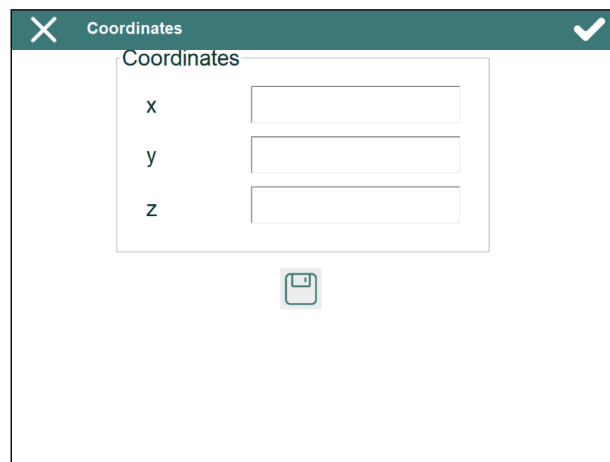
The name of the project's current points file is shown in the lower part of the screen. Clicking on the  button allows one to select any other points file.

Information about the points to be set out can be supplied by any of the following ways:


Individual: Sets out an isolated point. It shows the name of the first point in the currently selected file by default.

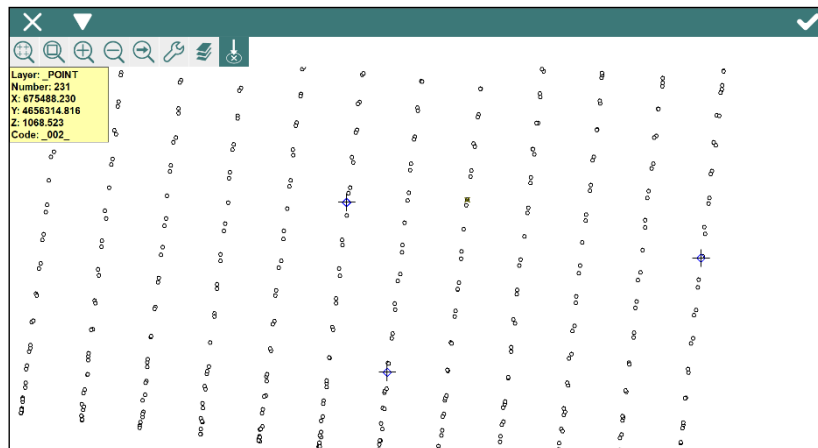


Manual: Allows one to manually enter the coordinates of the point to be set out. This point can be saved in the current file by clicking on the record button. It will be assigned with the number of the last point plus 1.



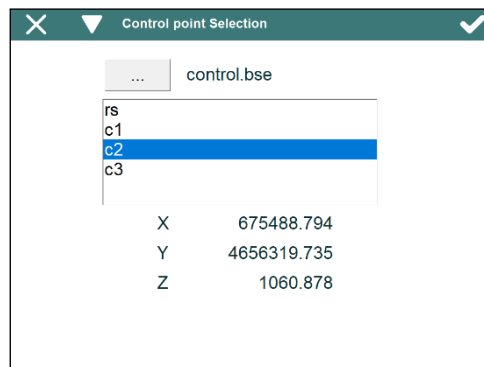
Code: Sets out the points of the file having the code indicated.

Graphic: Allows one to select a point or a control point graphically.  button must be clicked to select the point.

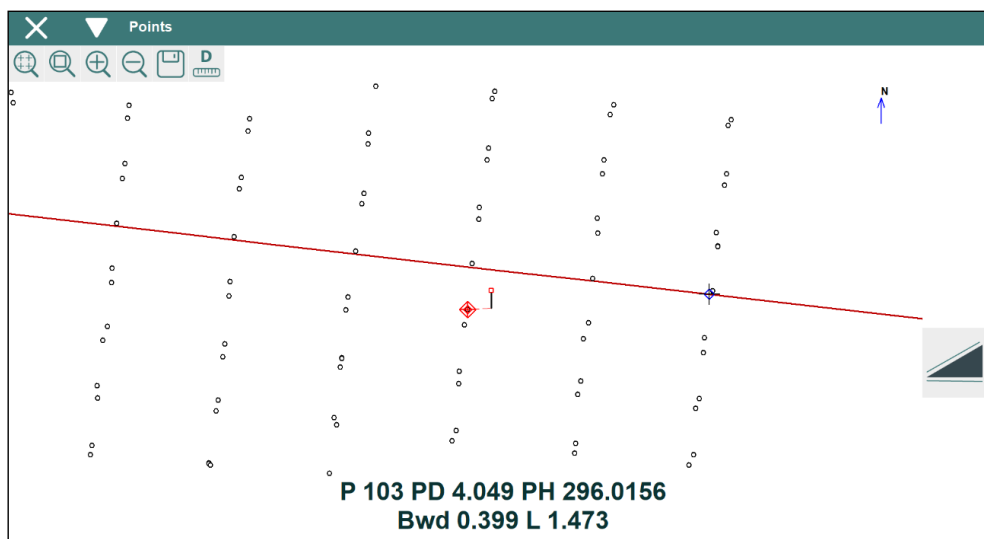


Interval: Allows one to set out from the initial to the final point in accordance with the interval entered. This marks the number of positions jumped within the file.

Control Point: Allows one to select a point from any station file.



Once the information of the point to stake out is supplied, the next screen appears:



P: Point number or name.

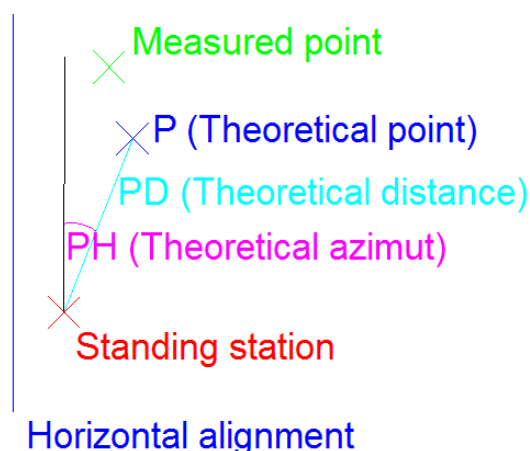
PD: Project or theoretical distance.

PH: Project or theoretical horizontal angle.

After measuring, this information is shown:

Bwd or **Fwd**: Distance to move backward or forward to reach the point.

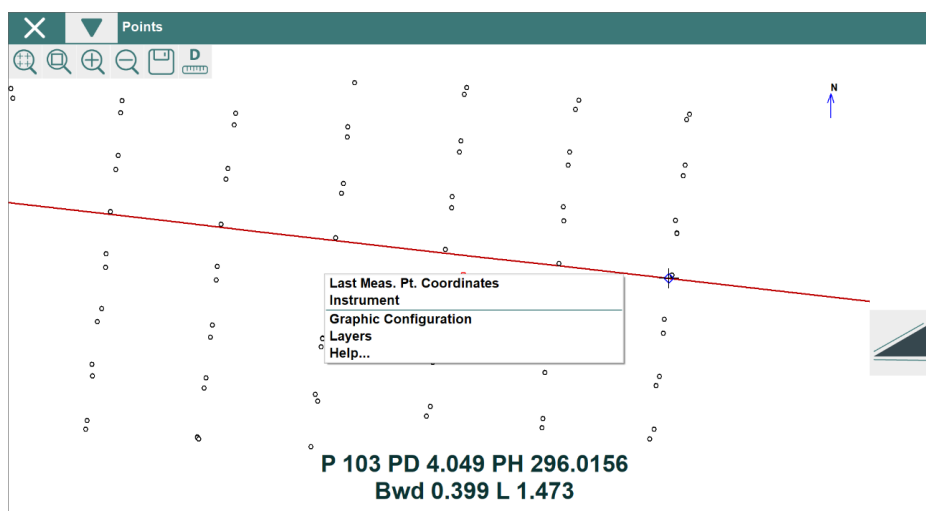
R or **L**: Move up or down (**R** or **L**) to reach the right height.



If the point is not in line, the program displays a prompt with the angle that the station must be moved to the right or to the left. In motorized stations, this information is not shown if the **Horizontal** and **Vertical** options have been selected in the [Instrument](#) section. The station will automatically move to the theoretical point.

The cross section and longitudinal tolerances are established in the **Settings** > [Tolerances](#) section. Both are in meters.

Other options are available in the menu on the title bar, such as indicate a point read by its name or number, viewing the coordinates of the last observed point, accessing the total station configuration, enabling/disabling layers of the drawing, etc.



6.5. Road Surface

Allows user to set out points over horizontal alignment entering a **Station** and an **Offset**. If there is a vertical alignment file in the project, it will be used to calculate the height of the point. Optionally, the user can enter a **Thickness** value, positive or negative, in addition to the calculated height.


Stake out Road Surface

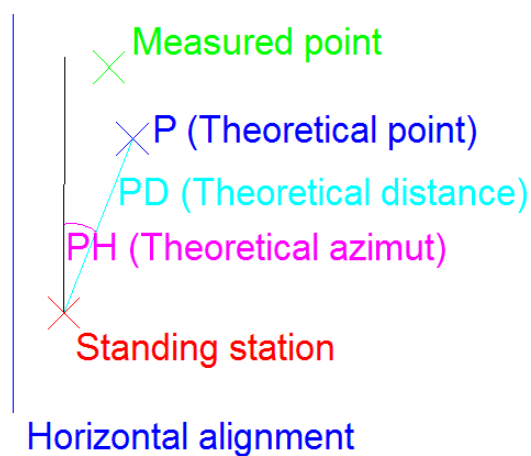
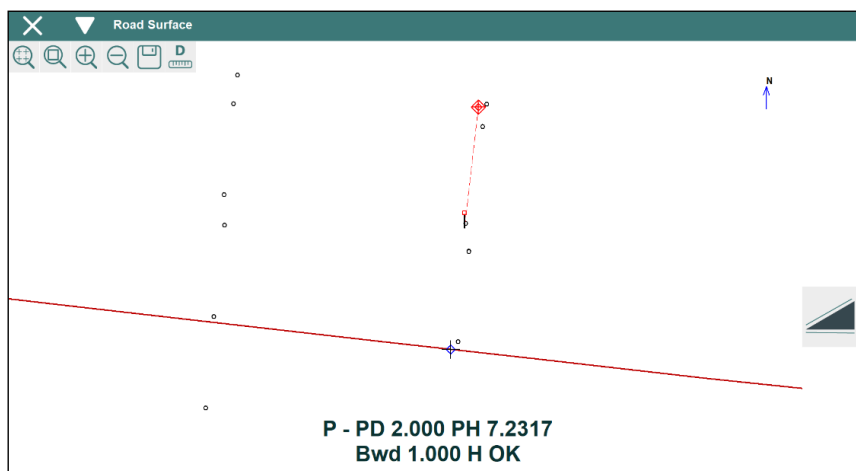
Station 100

Offset 2.0

Thickness 0.000

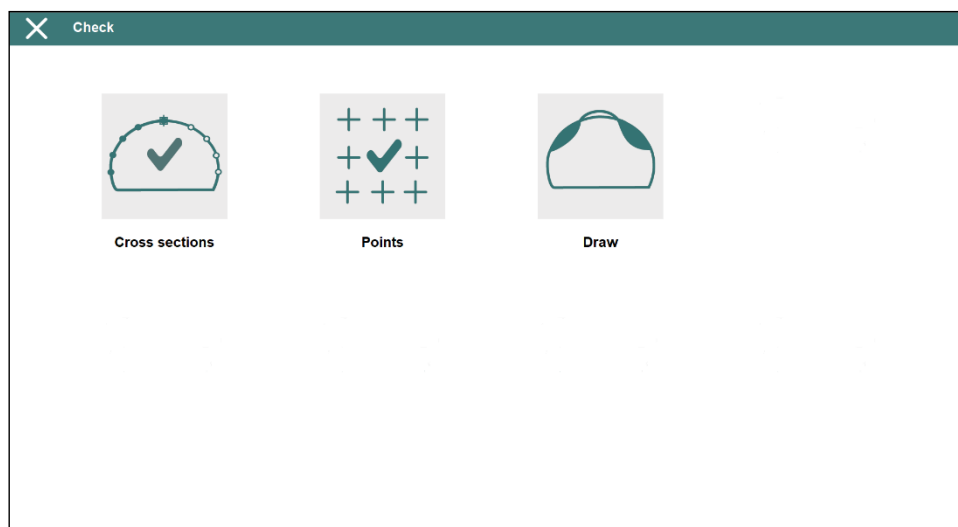
<





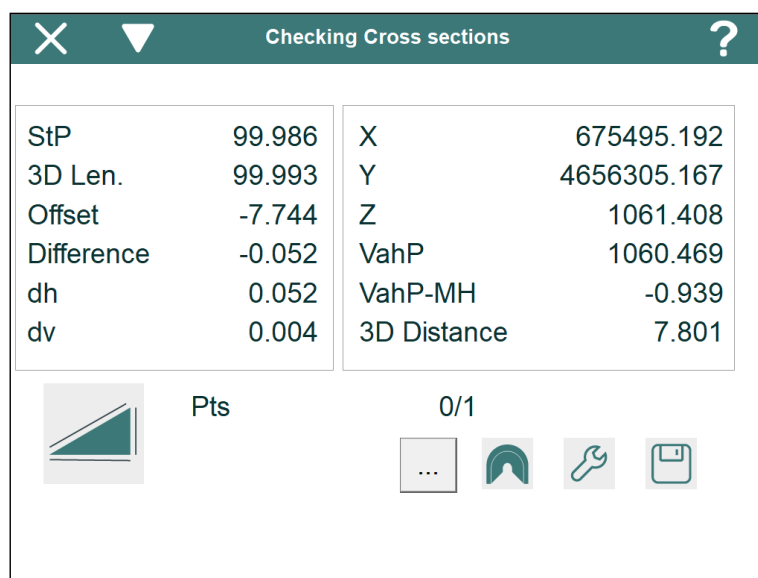
The staking out is performed in the same way as in the setting out [Points](#) option, appearing in this same chapter.

7. Checking



7.1. Cross Sections

Shows any differences existing between the measured points and tunnel template.



The following information is provided:

StP, Station of the profile of the point measured

3D Length calculated from the initial station of vertical alignment.

Offset regard with the horizontal alignment

Difference regard with the tunnel's theoretical cross-section

Horizontal (**dh**) and vertical (**dv**) differences between measured point and the point regard with tunnel template

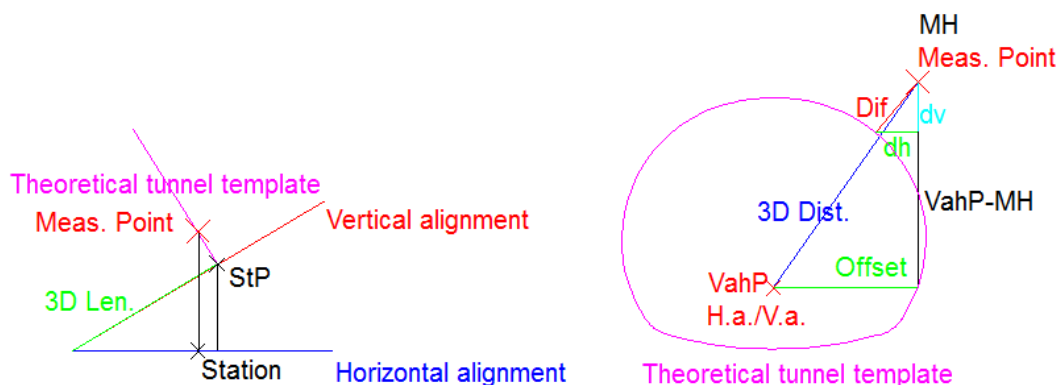
X, Y, Z coordinates of the point measured

The vertical alignment height ($VahP$) at StP

The difference between vertical alignment height at StP and the measured height ($VahP - MH$)

3D Distance between the measured point and the point calculated over horizontal alignment at StP


Pts , number of points stored and measured.



Also allows one to select a point from file click on  button.

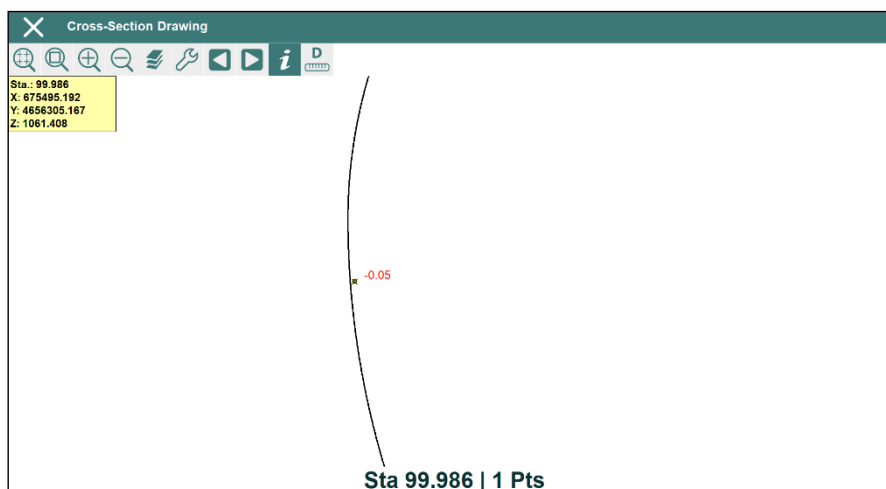
Each point measured can be recorded and viewed.

Tracking button, when available, enables this operation mode on total station and it allows to analyze points constant. Also these points are drawn in graphic mode.

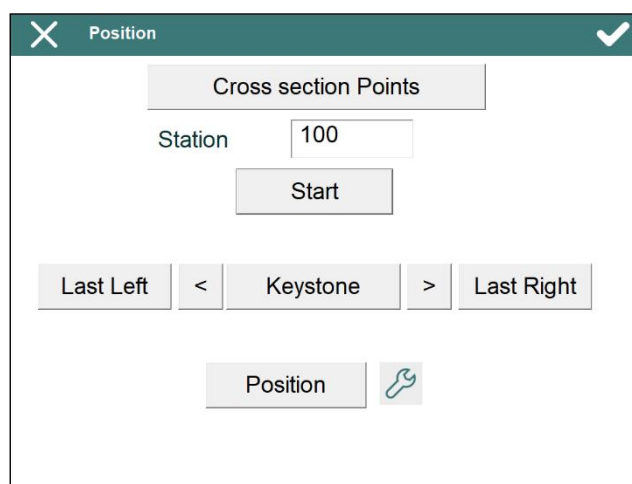
The point drawing () shows the tunnel template calculated for the last measured station as well as all measured points which their calculated StP are within the interval $[LastMeasuredStation - StationTolerance, LastMeasuredStation + StationTolerance]$. The station tolerance is set up within the option **Settings > Tolerances** and also it can be accessed through the **Tolerances** option within the menu of the title bar.

Checking Cross sections					
StP	99.986	X	675495.192		
3D Len.	99.993	Y	4656305.167		
Offset	-7.744	Z	1061.408		
Difference	-0.052	VahP	1060.469		
dh	0.052	VahP-MH	-0.939		
dv	0.004	Position...			
		Tolerances...			
		Help...			
		Pts	0/1		

When click on information button and select a measured point, the program shows the station and the coordinates X, Y, Z of that point and, also, the total station rotates to that point.



Position function, in the title bar menu, allows to rotate the total station to a theoretical point of the cross section on a entered station for checking this point.



To define the theoretical points into which the tunnel template is divided, the user must enter the theoretical station and click on **Cross-Section Points** button (see **Features and Functionality** > [Theoretical Points of the Tunnel Template](#)).

Once the data has been entered, the **Start** button should be clicked in order to position the station on any of the points calculated.


To change point, use the **Last Left** < **Keystone** > **Last Right** buttons.

When one presses **Position** button, the total station will move to the selected point. Then, when clicking on accept button, the total station will make a measurement for checking the point.

7.2. Points

Allows one to check the control points and indicates the distance and height differences between two measurements of the same point taken at different times.



The 'Checking Points' dialog box has a title bar with a close button (X) and a help button (?). It contains three input fields for coordinates: X (675495.978), Y (4656312.135), and Z (1059.078). Below the Z field are two buttons: '...' and 'Check'. To the right of the 'Check' button is a small icon of a wrench and screwdriver. Below these buttons is a section with three labels: 'dX', 'dY', and 'dZ'.

To start this process, one must set a point coordinates, by clicking on  button, and click the **Check** button. One is first asked to check the position to ensure the correct point is aimed at and then an measured is performed from the station to check the point.

7.3. Cross Sections Drawing

This option allows one to calculate and draw the cross-sections measured from a point cloud that is stored in one or more files. If there are tunnel templates in the project, the program allows calculate the under-excavation and over-excavation areas.

The 'Cross-Section Drawing' dialog box has a title bar with a close button (X) and a help button (?). It contains a section for 'Point Files' with a list box showing 'D:\project\exc.pun(2970 Analyzed - 2970 Projected)' and '+' and '-' buttons. Below this is an 'Analyze Points' button. Underneath, there are two rows of input fields: 'Align.' with 'Initial Sta.' (0.0000) and 'Final Sta.' (4205.3659), and 'Cloud' with 'Initial Sta.' (99.9310) and 'Final Sta.' (200.0076). At the bottom is a button labeled 'Calc. Cross sections >'.

At first, the user must select the files which stored the points to be analyzed. The   buttons allows user to add and remove, respectively, files from the list. Then, the **Analyze Points** button must be pressed. After finishing this process, the program will show the initial and final station which is the point cloud. The next screen of the wizard will be showing by clicking on **Calc. Cross Sections** button.

Cross-Section Drawing

	Initial Sta.	Final Sta.
Align.	0.0000	4205.3659
Cloud	99.9310	200.0076

Data for calculating cross sections

Sta. Interval	2	Initial Sta.	130.0
Sta. Tolerance	1	Final Sta.	140.0

☐ Calculate Areas

< Back

Draw Cross sections >

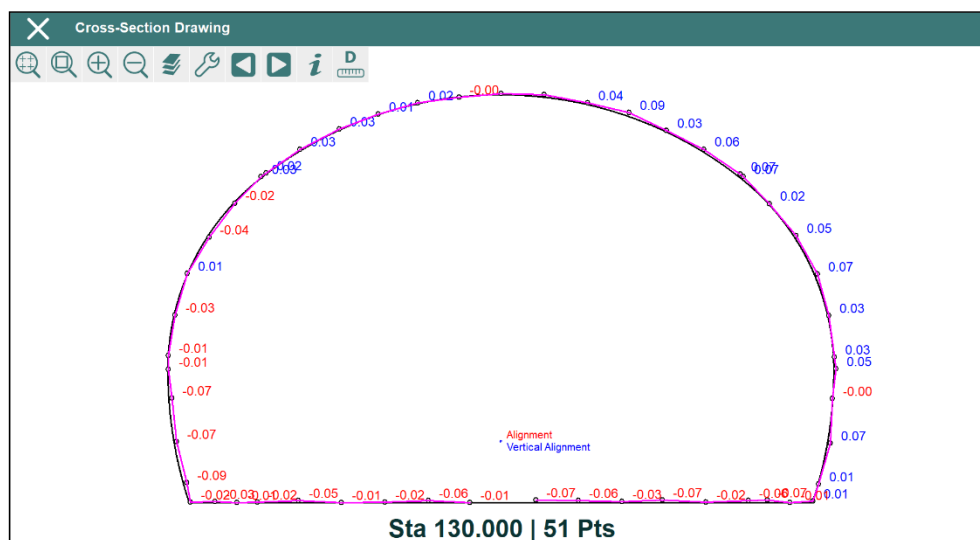
For calculating cross sections of the point cloud, the user must enter the following data:

Sta. Interval: Station increment value.

Initial Station

Final Station

Sta. Tolerance: If the difference between the theoretical and measured stations is less than this value, the program includes this point into the measured cross-section.



Show the previous cross section.



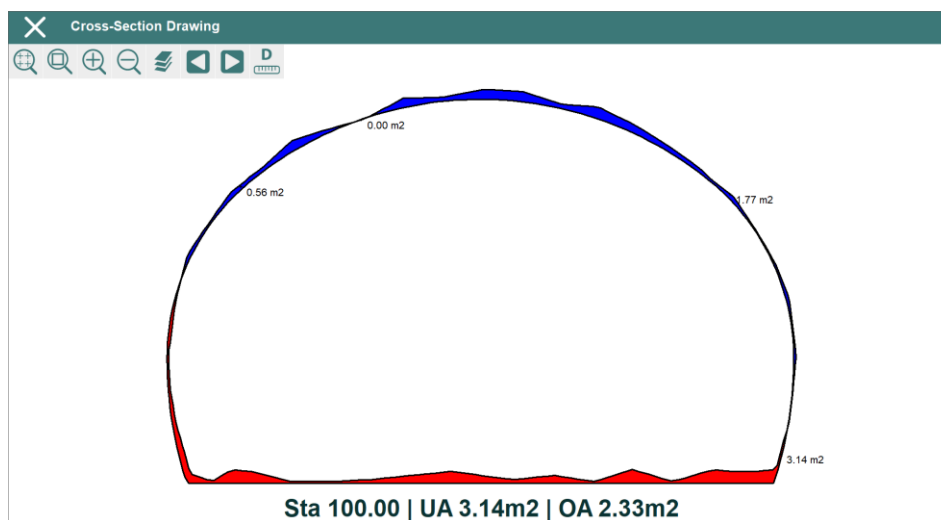
Show the next cross section.



Turn the total station to the selected point. Also, it shows coordinates of the point.

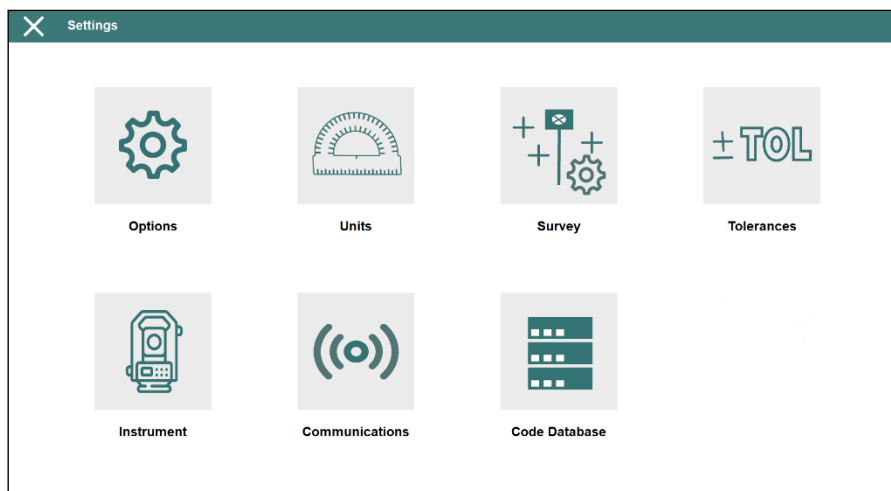
Calculate Areas

If the user checks this option in the previous screen, the program calculates the underbreak and overbreak areas for each cross-section. This option will be disabled if there are not tunnel templates in the project.



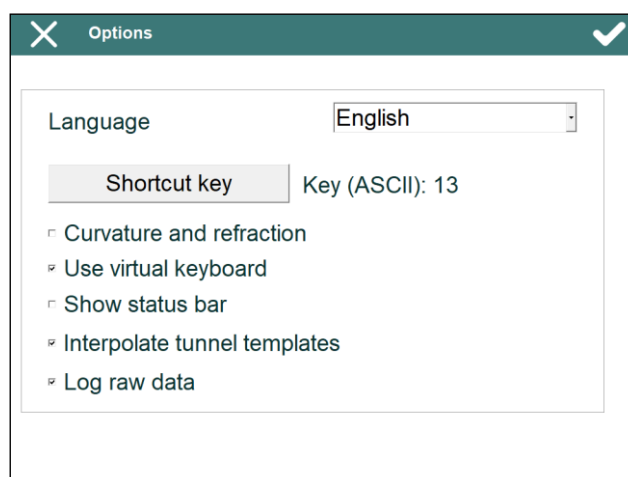
The program shows the *Station* and the number of points for each cross-section if *Calculate Areas* option is not checked. Otherwise, the program shows information about underbreak (*UA*) and overbreak (*OA*) areas.

8. Settings



8.1. Options

The parameters that can be configured in this window are as follows:



Language: Allows one to change the language of the application. The program must be restarted to apply the changes.

Shortcut Key: Physical key for measuring points in several options (points measurement, checking cross-sections and points and setting out road surface and points).

Curvature and Refraction: Indicates whether this coefficient should be applied to calculate the measured points' heights. It is important to ensure that this coefficient is only taken into account at the total station or by the application to avoid calculation errors.

Use virtual keyboard: Allows one to enable or disable the virtual keyboard.

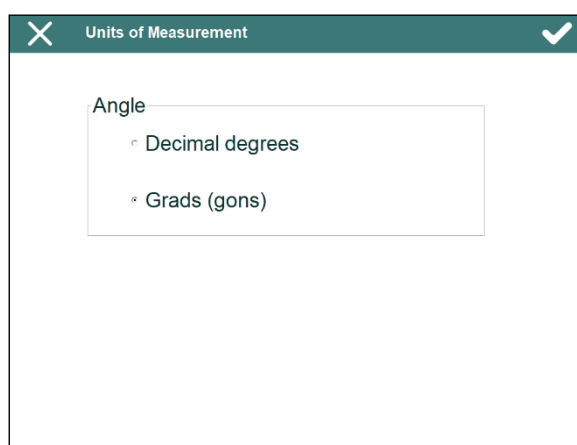
Show Status Bar: Allows one to enable or disable the display, in real time, of the horizontal y vertical angles within the options where the program make measurements.

Interpolate Tunnel Templates: If the project has different tunnel templates assigned along the horizontal alignment, the program allows one to create an interpolated tunnel template for each station that has been measured.

Log Raw Data: Allows one to save the raw information from each measurement. See section **File Management** > [Raw Data](#).

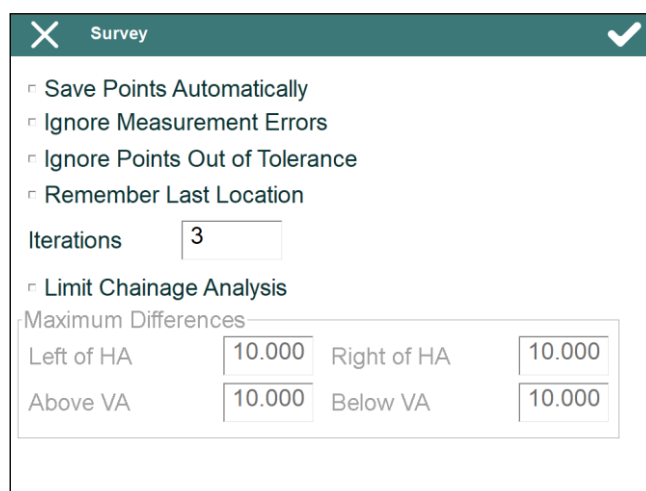
8.2. Units of Measurement

Allows user to set the angular units in which the program works.



8.3. Survey

In this section, the user can set up several parameters regarding with survey and set out data.



Save Points Automatically: Each measured point within **Survey** > **Point** and **Checking** > **Cross sections** options will be stored automatically after measuring it, otherwise, several measurements can be done without stored the point.

Ignore Measurement Errors: Allows one to set out and survey cross-sections without inform about measurement and rotation errors of the total station. When an error occurs, the program continues with the next iteration or point.

Ignore Points Out of Tolerance: Within setting out and surveying cross-sections options, the program won't ask about storing the point if the station difference is bigger than setting tolerance.

Remember Last Location: This option is used also within setting out and surveying cross-sections and it allows one to calculate a new point using the last difference calculated regarding with tunnel template.

Iterations: Set up the number of iterations that the program does, when setting out or surveying, for trying to meet the setting tolerances. This parameter is used within setting out the front and setting out and surveying cross-sections.

Limit Chainage Analysis: This option allows one to enable/disable the limits for analysing stations. This feature is useful for spiral horizontal alignments. The program ask for maximum distances to the left and right of the horizontal alignment and up and down of the vertical alignment.

For each point, the program will calculate several solutions along the horizontal alignment and, then, it select the first station where the point is below the stablished distances.

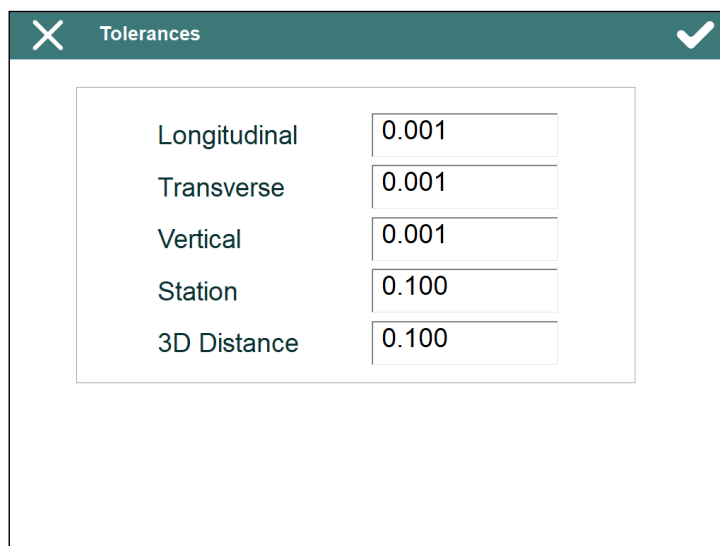
8.4. Tolerances

In this option, the user can set the tolerances for surveying and setting out options.

Longitudinal, **Transverse** and **Vertical** tolerances are used for setting out points and setting out road surface. For setting out rock bolts only the vertical one is used. Below these values the points are considered to be set out.

The **Station** tolerance is used for setting out, surveying and checking cross-sections. If the station of a point measured is within the interval $[\text{TheoreticalStation} - \text{StationTolerance}, \text{TheoreticalStation} + \text{StationTolerance}]$, this point is considered to be a point of cross-section of the theoretical station.

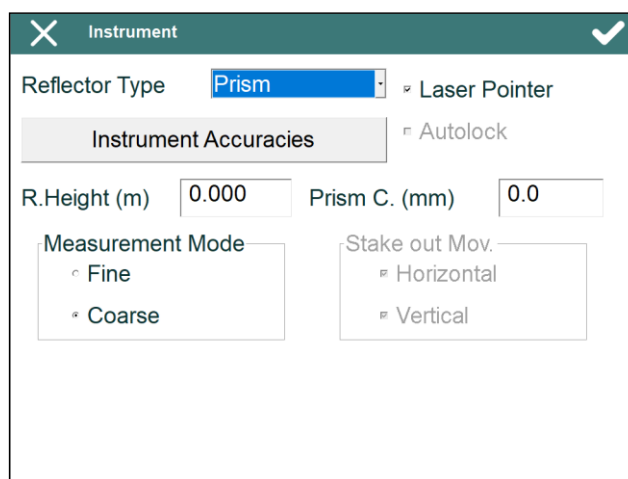
The **3D Distance** tolerance is used for setting out the front of the tunnel. A point is considered to be set out if the distance between the theoretical point on measured station and measured point is below this value.



Tolerances	
Longitudinal	0.001
Transverse	0.001
Vertical	0.001
Station	0.100
3D Distance	0.100

8.5. Instrument

The total station's various parameters that depend on its characteristics are configured by this option.



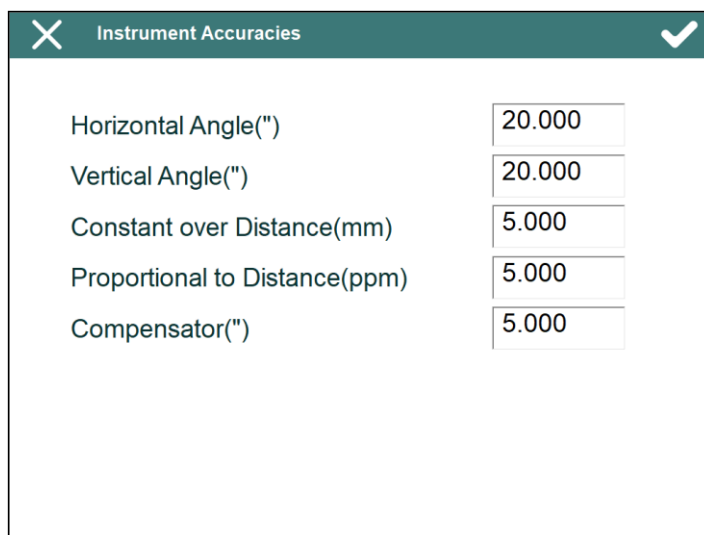
Instrument	
Reflector Type	Prism
<div> <div>Instrument Accuracies</div> <div> <div>R.Height (m)</div> <div>0.000</div> </div> <div> <div>Prism C. (mm)</div> <div>0.0</div> </div> </div>	
<div> <div>Measurement Mode</div> <div> <div>Fine</div> <div>Coarse</div> </div> </div>	<div> <div>Stake out Mov.</div> <div> <div>Horizontal</div> <div>Vertical</div> </div> </div>

Reflector Type: Depending on the total station features, the program will show *Prism*, *Reflector Sheet*, *Reflectorless*, etc.

Laser Pointer: Allows one turn on/off the laser pointer of the total station.

Autolock: Allows one turn on/off the automatic search of the prism.

Instrument Precisions: Accuracy parameters of the total station, used within resection calculation, for calculating uncertainties of angles and distances.



Instrument Accuracies	
Horizontal Angle('')	20.000
Vertical Angle('')	20.000
Constant over Distance(mm)	5.000
Proportional to Distance(ppm)	5.000
Compensator('')	5.000

R.Height (m): Allows one to change the reflector height (meters). This option is available only for **Prism** and **Reflector Sheet**.

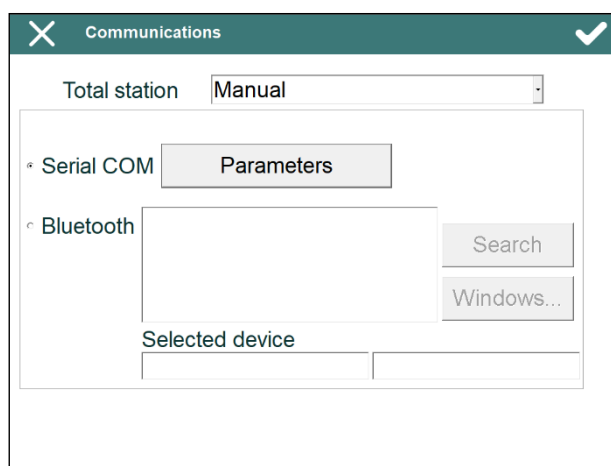
Prism C. (mm): Allows one to change prism constant (milimeters)

Measurement Mode: Sets the accuracy for the measurements.

Setting Out Mov.: One can indicate if servo-assisted stations should be automatically rotated horizontally and/or vertically within setting out options.

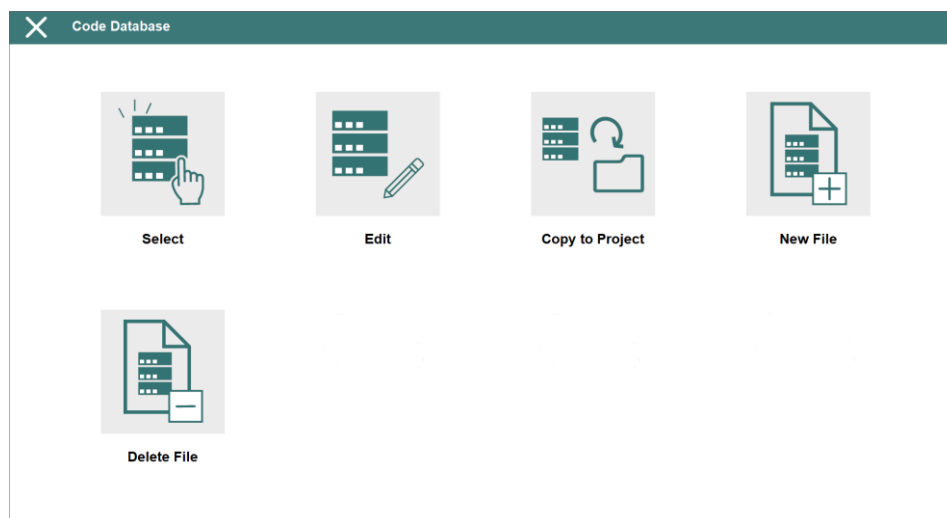
8.6. Communications

This section allows one to select the brand and model of the total station and set up the communication between the device and the total station. Depending on the total station selected, **Bluetooth** option will be available. In this case, the instrument can be selected doing a Bluetooth search (**Search**) or directly from the Windows Bluetooth manager (**Windows**). Also, Bluetooth MAC address can be entered manually.



Communications	
Total station	Manual
Serial COM	Parameters
Bluetooth	<div>Search</div> <div>Windows...</div>
Selected device	

8.7. Codes Database



Allows one to view and modify the database that stores the codes available in survey points option.

1.1.1. Select

This allows the selection of the data base file which will be used in the different program options.

1.1.2. Edit

This allows the editing of the database codes. This database is shared by several programs from Aplitop. TcpTunnel only uses the **Code** field within **Survey > Points**. The database contains the following fields:

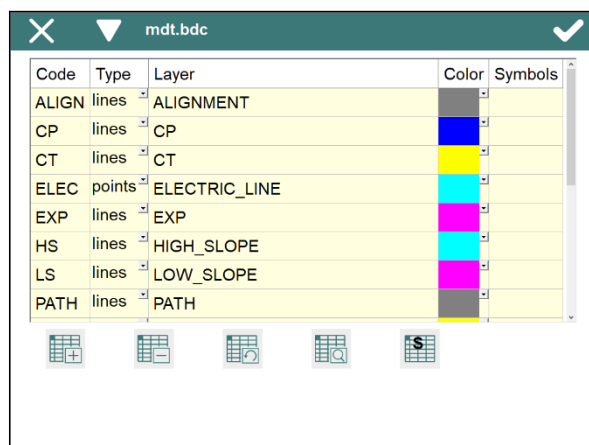
Code: Code name which will be stored in the points file.

Type: Code type which may be **Point** or **Line**. Point type elements are usually associated in the subsequent drawing in CAD with a block (posts, utility boxes etc.) whilst those of the line type are used to connect some points with others by means of polylines.

Layer: Layer on which the corresponding blocks or polylines will be drawn.

Color: Color of the entities drawn.

Symbol: For point type codes reference is made to the symbol which will represent the code in the different graphic options of the application. Each symbol will be drawn on a layer with the code name it represents so that said layer can be managed on the list of layers of the graphic option.



1.1.3. Copy to Project

This option allows the current data base of the application to be copied to the active project directory. A screen will be shown requesting the new name.

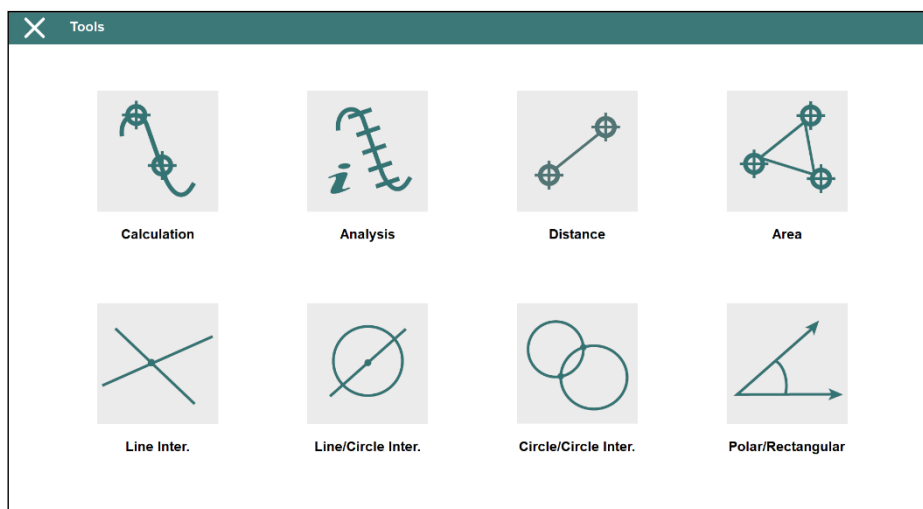
1.1.4. New File

This allows a new data base file to be created. The new file will be established as the current data base of the application.

1.1.5. Delete File

This allows the active data base file to be deleted if it is not the file which incorporates the program by default, MDT.bdc

9. Tools



9.1. Point Calculation

By entering a *Station* and *Offset* and clicking on the *Calculate* button, the coordinates of the corresponding point are shown on screen, along with the other parameters described below.

The 'Points on Alignment' window displays the following information:

Station: 150
Offset: 2.5

Calculate [Save Icon]

x	675446.708
y	4656321.234
Azimuth	307.8147
Radius	5350.000
VAH	1059.929
Slope	-0.010

X coordinate of the point.

Y coordinate of the point.

Azimuth of the station entered.

Radius of the station entered.

VAH, vertical alignment height of the station entered. It is only shown if there is a vertical alignment file in the active project. (**Sup**) suffix indicates that height is calcuted with superelevations (if there is a superelevations file in the active project).

Slope of the vertical alignment in the section to which the station entered belongs. Similarly to the previous data, it is only shown if there is a vertical alignment file in the active project.

9.2. Point Analysis

Allows one to know the station and the offset with regard to the current position's alignment.

Point Analysis	
X	675495.256
Y	4656305.299
Z	1060.446
<div>...</div> <div>Save</div>	
Station	99.937
3D Len.	99.944
Offset	-7.606
VAH	1060.470
VAH - MH	0.024

It's allowed at all times to save the current point coordinates. This is stored in the file points with the number of the last point plus 1.

The data shown are as follows:

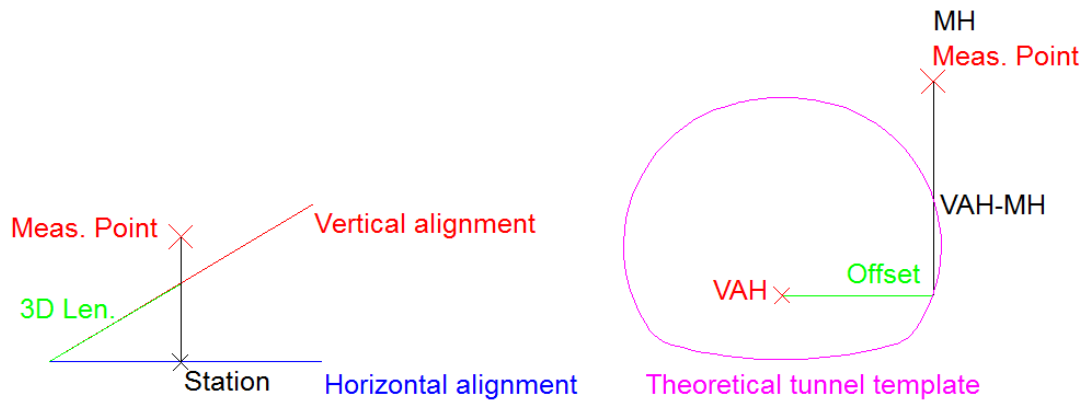
Station analyzed or measured.

3D Length from the initial station.

Offset with regard to the horizontal alignment of the position indicated. A negative value indicates that the point is to the left of the alignment and a positive value indicates that it is to the right.

VAH, vertical alignment height.

VAH – MH: Difference between the vertical alignment height and the current height.



9.3. Distance between Points

This command calculates the distance there is between two points contained in the project file selected.

×

Distance between Points

Initial Point

250

Final Point

260

Calculate

Distance	10.757
Azimuth	219.5961
Slope	0.002
dX	3.259
dY	10.251
dZ	-0.017

By entering two numbers and clicking on the **Calculate** button, the following information is shown on screen:

Distance between the points indicated.

Azimuth between the two points.


Slope between the points indicated.

dX: Difference in X coordinates.

dY: Difference in Y coordinates.

dZ: Difference in Z coordinates.

9.4. Area between Points

Based on a sequence of points that are designated graphically and after pressing the  button, the surface and the perimeter delimited by that sequence are displayed. If one

only one point is designated, its X, Y coordinates are displayed and if two points are designated, the distance and the azimuth are displayed.



The specific functions of this option are:



Enables the menu that allows one to calculate areas and distances.



Adds the points selected for calculating areas and distances.



Deletes the last point selected for calculating areas and distances.



Calculates area and distance with the selected points.

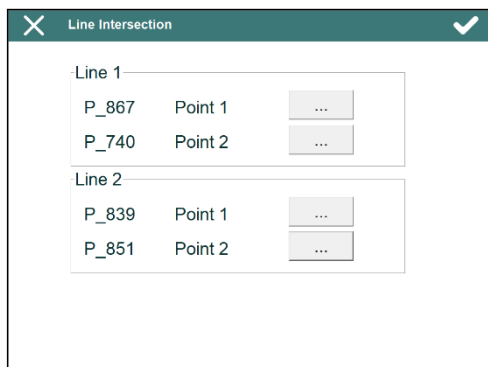


Disables the area and distance calculation menu.

9.5. Line Intersection

This option allows one to calculate the intersection point of two straight lines.

It can be saved in the current project's points file.



Line Intersection

Line 1

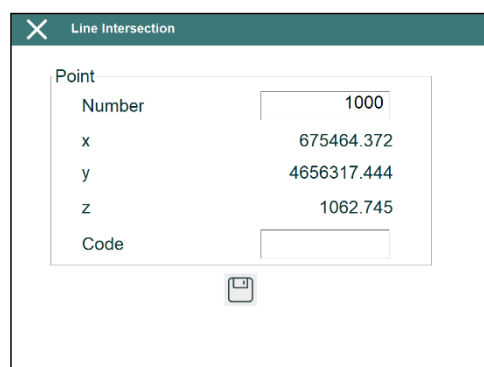
P_867 Point 1 ...

P_740 Point 2 ...

Line 2

P_839 Point 1 ...

P_851 Point 2 ...



Line Intersection

Point

Number 1000

x 675464.372

y 4656317.444

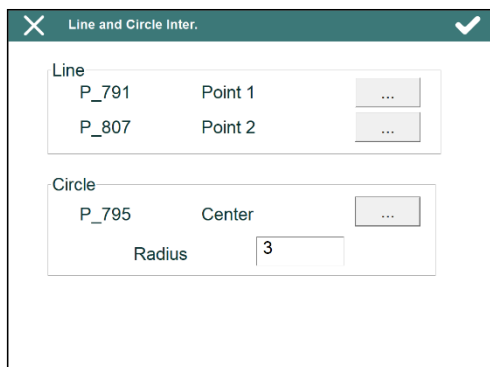
z 1062.745

Code

9.6. Line and Circle Intersection

The option calculates the intersection point or points between a straight line and a circle.

Any of the two solutions can be selected and the one chosen is saved in the project's points file.



Line and Circle Inter.

Line

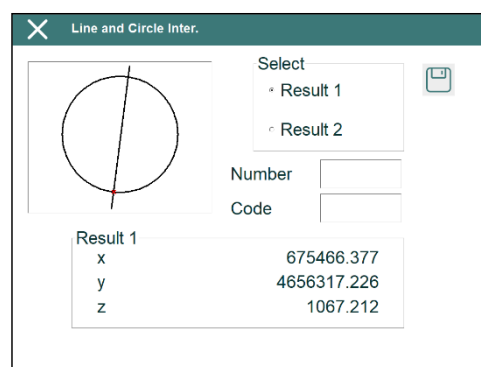
P_791 Point 1 ...

P_807 Point 2 ...

Circle

P_795 Center ...

Radius 3



Line and Circle Inter.

Select

Result 1

Result 2

Number

Code

Result 1

x 675466.377

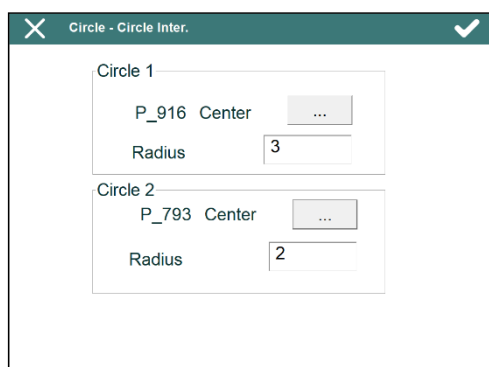
y 4656317.226

z 1067.212

9.7. Circle and Circle Intersection

The intersection point or points between two circles are calculated through this option.

Any of the solutions can be recorded in the current project's points file.



Circle - Circle Inter.

Circle 1

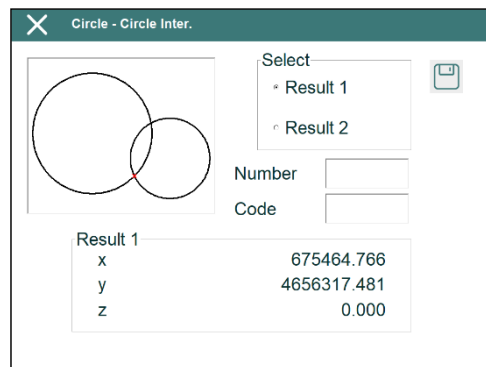
P_916 Center ...

Radius 3

Circle 2

P_793 Center ...

Radius 2



Circle - Circle Inter.

Select

Result 1

Result 2

Number

Code

Result 1

x 675464.766

y 4656317.481

z 0.000

9.8. Polar to Rectangular Coordinates

The coordinates of a new point are calculated from a point, a distance and an azimuth.

Polar to Rectangular

Point

P_6

...

Distance

3.5

Azimuth

150.0

Number

x

675497.907

y


4656304.692

z

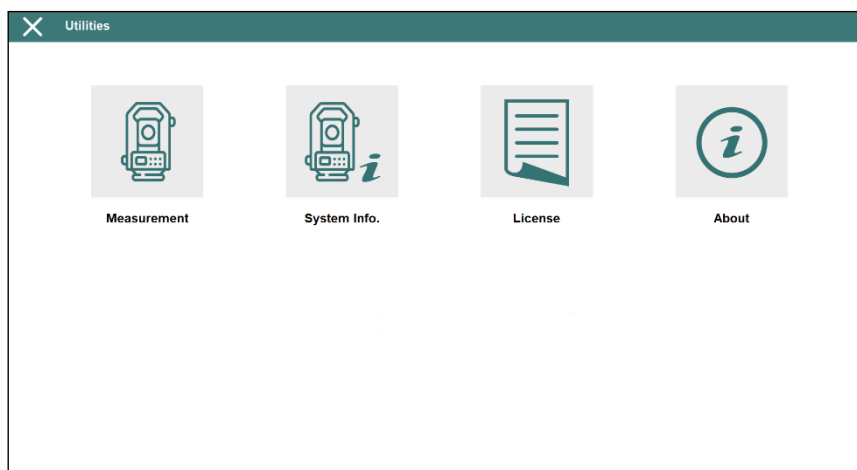
1059.078

Code

Calculate



10. Utilities



10.1. Measurement

Allows one to perform observations from the total station in order to test the devices communications. The coordinates of the point measured will only be shown if the station has been previously oriented.

The screenshot shows a window titled 'Measurements' with a close button (X) in the top left corner. Inside the window, there is a table with two columns of data. Below the table, there are two icons: a surveying instrument and a wrench.

SD	12.554	X	675500.925
HD	12.549	Y	4656324.428
H	25.3771	Z	1060.817
V	98.2365	Z Dif	0.348

The program will show the data below for each measurement:

SD: Slope distance (meters).

HD: Horizontal distance (meters).

H: Horizontal angle (the units depend on the setting value).

V: Vertical angle (the units depend on the setting value).

X: Measured point's *X* coordinate.

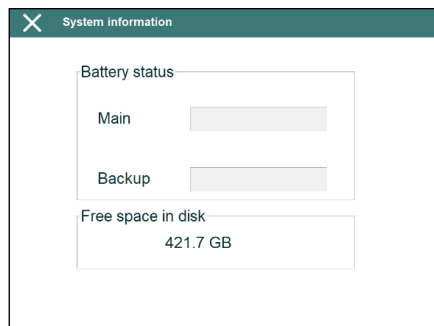
Y: Measured point's *Y* coordinate.

Z: Measured point's *Z* coordinate.

Z Dif: Measured point's height difference compared to standing station.

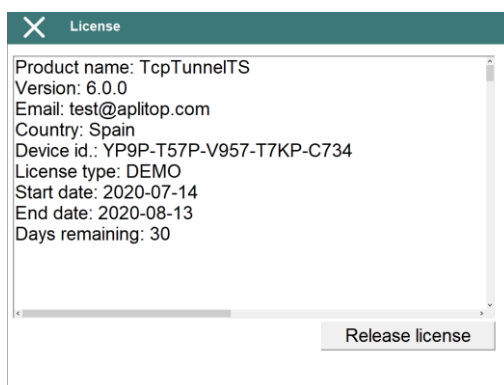
10.2. System Information

This option shows information on **Free space in disk** for files (in GB) where the current project is to be found, as well as the field data recorder's **Main Battery Status** and **Backup Battery Status** (in %).



10.3. License

This option shows the license data of the program, such as **Product name**, **Version**, **Email**, **Country**, etc.



The **Release license** button allows one to remove the current license from the device. After doing this, the program will be closed and it will be necessary to request a new activation the next time it is run.

10.4. About

This window shows information about the application's version, as well as on its compilation date.



11. Abbreviations

Abbreviation	Description
3D Len.	3D length
Bck	Backward
Cont.	Continue
Control Pt.	Control point
dh	Horizontal difference
Dif.	Difference
Dist.	Distance
dv	Vertical difference
Dwn	Down
Fwd.	Forward
Gd	Geometric distance
H	Horizontal angle
H OK	Height OK
HC	Horizontal correction
Hd	Horizontal distance
Instr. Height	Instrument height
L	Low
MH	Measured height
M StP	Measured station of the profile (cross section)
Max. Dif.	Maximum difference
P	Point
PH	Project height
PD	Project distance
P StP	Project station of the profile (cross section)
Pts	Points
R	Raise
Rms	Root mean squared error
Scl.	Scale
Sta.	Station (Chainage)
Standing St.	Standing station
Std. Dev.	Standard deviation
StP	Station of the profile
Sup	Superelevations
V	Vertical angle
VAH	Vertical alignment height
VahP	Vertical alignment height of the station of the profile
Z Dif.	Height difference