SPT-Liq

2023

SPT-Liq v1.0

SPT-N Based Liquefaction Assessment Software

(1) Main Goals and Objectives

SPT-Liq v1.0 was developed in order to provide a soil liquefaction assessment tool based on SPT-N data collected from the soil investigation. This software utilized several simplified methods for the liquefaction assessment. Besides, this software also provide the three-dimensional mapping of soil liquefaction hazard and physical properties by using linear interpolation method. The main functions of SPT-Liq v1.0 are:

① Liquefaction assessment based on SPT-N data

② Three-dimensional mapping and visualization of the predicted liquefaction hazard and soil physical properties in the form of surface plot.

(2) Short Review of Features

SPT-Liq v1.0 is a computer program utilizing GUI environment mainly intended to provide soil liquefaction assessment based on SPT-N data. The computation results are in the form of data array, and able to be interpolated to generate soil liquefaction hazard and physical properties map, and visualized into two- or three-dimensional surface plot. A brief summary of the software are as follows:

Soil Investigation Data: In the "Soil Investigation Data" tab, the user can import acquired soil investigation data, consisting SPT-N value on every depth and other related properties for the liquefaction assessment. The user can also choose to involve or not to involve each soil layer in the liquefaction assessment individually.

Liquefaction Assessment: The liquefaction assessment at each borehole location can be performed in the "Liquefaction Assessment" tab. The user needs to choose the liquefaction assessment method and select or input related parameters in this tab for performing the calculation. The user can acquired the factor of safety against liquefaction (FS) and liquefaction potential index (PL) based on the imported data in the previous tab (Soil Investigation Data).

Soil Investigation Data Plot: In this tab, three properties from soil investigation data are plotted in three graphs: 1) SPT-N/N60/(N1)60, 2) Fines Content (FC), and 3) D50.

Liquefaction Assessment Plot: In this tab, the vertical stress profile and liquefaction assessment results are plotted in four graphs. 1) Vertical Total Stress/Effective Stress, 2) Cyclic Resistance

Ratio (CRR), 3) Factor of Safety (FS), and 4) F.w(z) for Calculating The Liquefaction Potential Index (PL) on Every Depth.

3D Visualization: The "**3D Visualization**" tab provides the user with two- and three-dimensional map of the predicted soil liquefaction hazard and physical properties. The user is able to choose the properties to be plotted and visualized it into surfaces or planes orthogonal to the x-, y-, and z- axis.

Predicted Soil Index Plot: Similar like the "**Soil Investigation Data Plot**" tab, this tab displays the predicted soil properties are plotted in three graphs: 1) SPT-N/N60/(N1)60, 2) Fines Content (FC), and 3) D50.

Liquefaction Assessment Plot (Prediction): Similar like the "**Liquefaction Assessment Plot**" tab, the vertical stress profile and liquefaction assessment results from the previously mentioned predicted soil properties are plotted in four graphs. 1) Vertical Total Stress/Effective Stress, 2) Cyclic Resistance Ratio (CRR), 3) Factor of Safety (FS), and 4) F.w(z) for calculating the liquefaction potential index (PL) on every depth.

(3) System Requirements

① Operating Systems:
   a. Windows 10 (version 1803 or higher)
   b. Windows 7 Service Pack 1
   c. Windows Server 2019
   d. Windows Server 2016

② Processors: Any Intel or AMD x86-64 Processor

③ Disk Space: 1 GB

④ RAM: 4GB

⑤ Graphics: No specific graphic card is required. Hardware accelerated graphics card supporting OpenGL 3.3 with 1GB GPU memory is recommended.

(4) Program Algorithm

The SPT-Liq v1.0 is a computer program developed using the MATLAB®graphical user interface (GUI) environment. The main feature of this software is the soil liquefaction assessment feature, where the user can do the soil liquefaction analysis by using SPT-N and other related properties acquired from the soil investigation. The liquefaction assessment performed in this software is based on four simplified methods: 1) Japan Design Specification of Highway Bridge,

2) Korean Liquefaction Assessment Method, 3) Seed and Idriss (1982), and 4) Youd et al. (2001). Besides, this software is also able to generate soil liquefaction hazard and physical properties mapping by using interpolation method. The user can choose between ground surface elevation, ground water level, SPT-N value, soil type/classification, fines content (FC), D50, factor of safety (FS), and liquefaction potential index (PL) as the available properties to be mapped and visualized in this feature.

The software program was developed in order to perform the following specific functions:

① Soil liquefaction assessment based on SPT-N data by using simplified liquefaction assessment method.

② Providing the soil liquefaction hazard and physical properties prediction based on linear interpolation method.

③ 2D and 3D visualization of the predicted soil liquefaction hazard and physical properties in the form of surface plot.

The workflow of the program can be seen in [Fig 1]. Initially, the soil investigation data from the boreholes that are going to be analyzed needs to be imported. The imported data has to be written in the excel file and follow specific formatting for the data to be read well by the software. The SPT-N value, fines content, and D50 from the imported data will be plotted on the graphs. After importing the required soil investigation data with the determined format, the user can choose to include or exclude particular soil layers in the liquefaction assessment. The excluded soil layers will be automatically result in factor of safety equal to one. The other layers will be going through the liquefaction assessment process.

The process continue to the liquefaction assessment, where four simplified methods are available for the user to choose. The simplified method for liquefaction assessment by Japan Design Specification of Highway Bridge, Korean Liquefaction Assessment Method, Seed and Idriss (1982), and Youd et al. (2001) were utilized in the coding of SPT-Liq v1.0. For performing the assessment, the user needs to input and select other related properties such as SPT-N correction factors, depends on the chosen assessment method. After completing the data input and selection, the liquefaction assessment can be proceed. The calculation results will be shown in the table and the summarized results can be exported into an excel file. The table consists of the combination of the imported soil investigation data and the calculated properties related to the liquefaction assessment. The calculated vertical stress profile, cyclic resistance ratio (CRR), FS, and F.w(z) will be plotted on the graphs at the "Liquefaction Assessment Plot" tab in the GUI.

Lastly, the user is able to generate the soil liquefaction hazard and physical properties map based on the collected soil investigation data from each borehole. Linear interpolation is utilized

in this software to interpolate the unknown data between the boreholes. The interpolated value then visualized into interactive three-dimensional plot in the software. Besides, the user is able to get the predicted liquefaction potential or soil properties at a specific location inside the interpolation area by inputting the x- and y-coordinate. Similar like the liquefaction assessment data, the prediction results will be shown in the table and the summarized results can be exported into an excel file. The calculation and prediction results acquired from this software are useful to be considered for the geotechnical analysis, foundation design, etc.

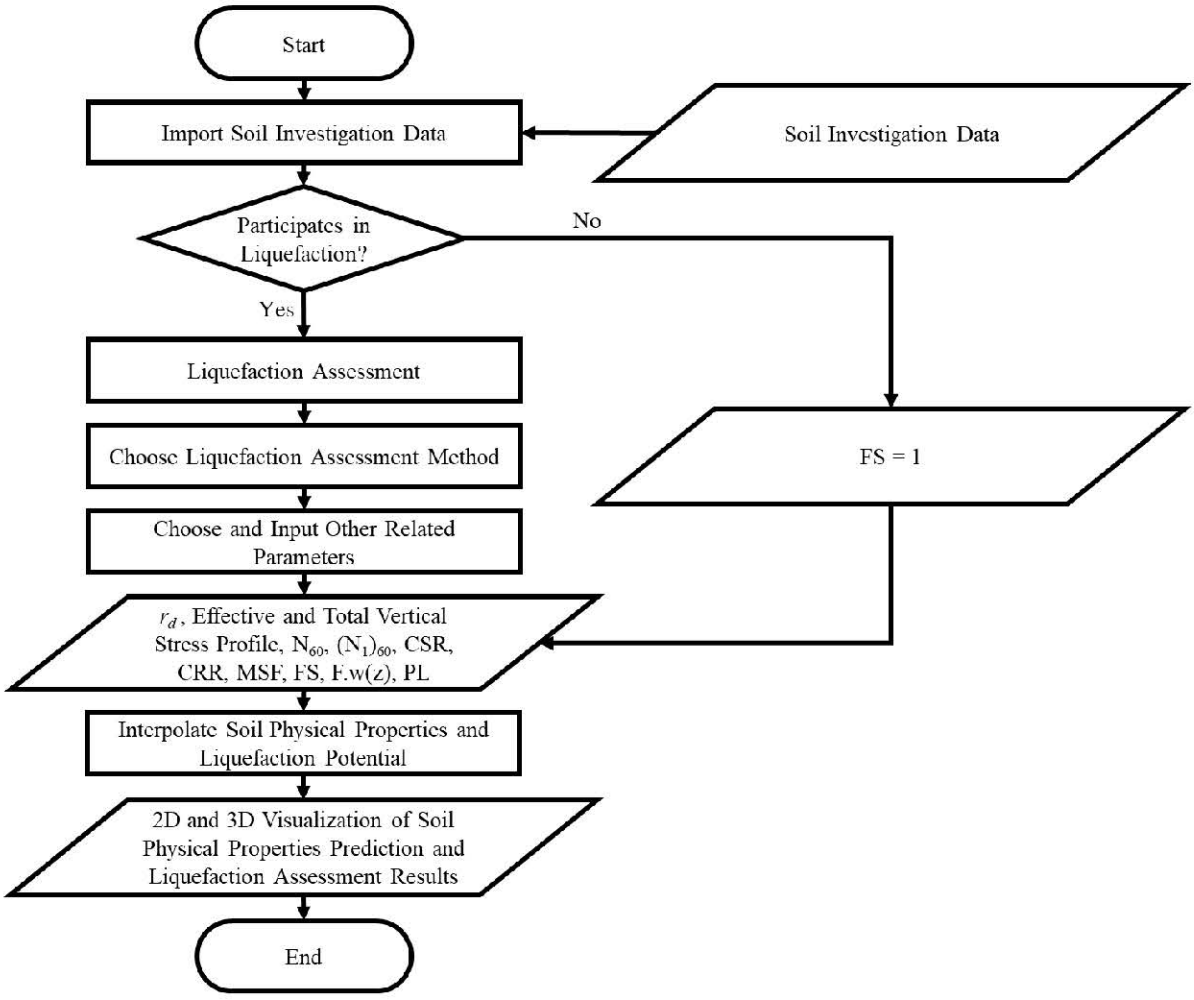


Fig. 1 Flowchart for SPT-Liq v1.0 Program

(5) Use of SPT-Liq v1.0 Software

- Getting Started

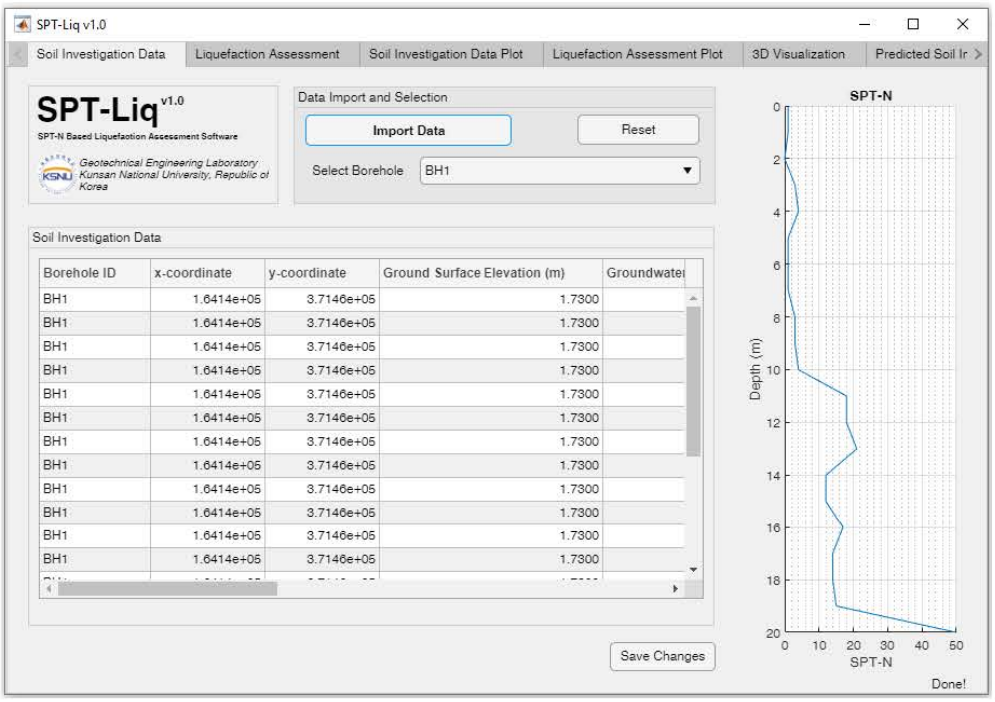


Fig. 2 SPT-Liq v1.0 Graphical User Interface (GUI)

SPT-Liq v1.0 is a program designed for the soil liquefaction assessment based on SPT-N data, and to generate liquefaction hazard and physical properties prediction map. This quick start tutorial will familiarize the user with the features of SPT-Liq v1.0.

- **Soil Investigation Data Tab**

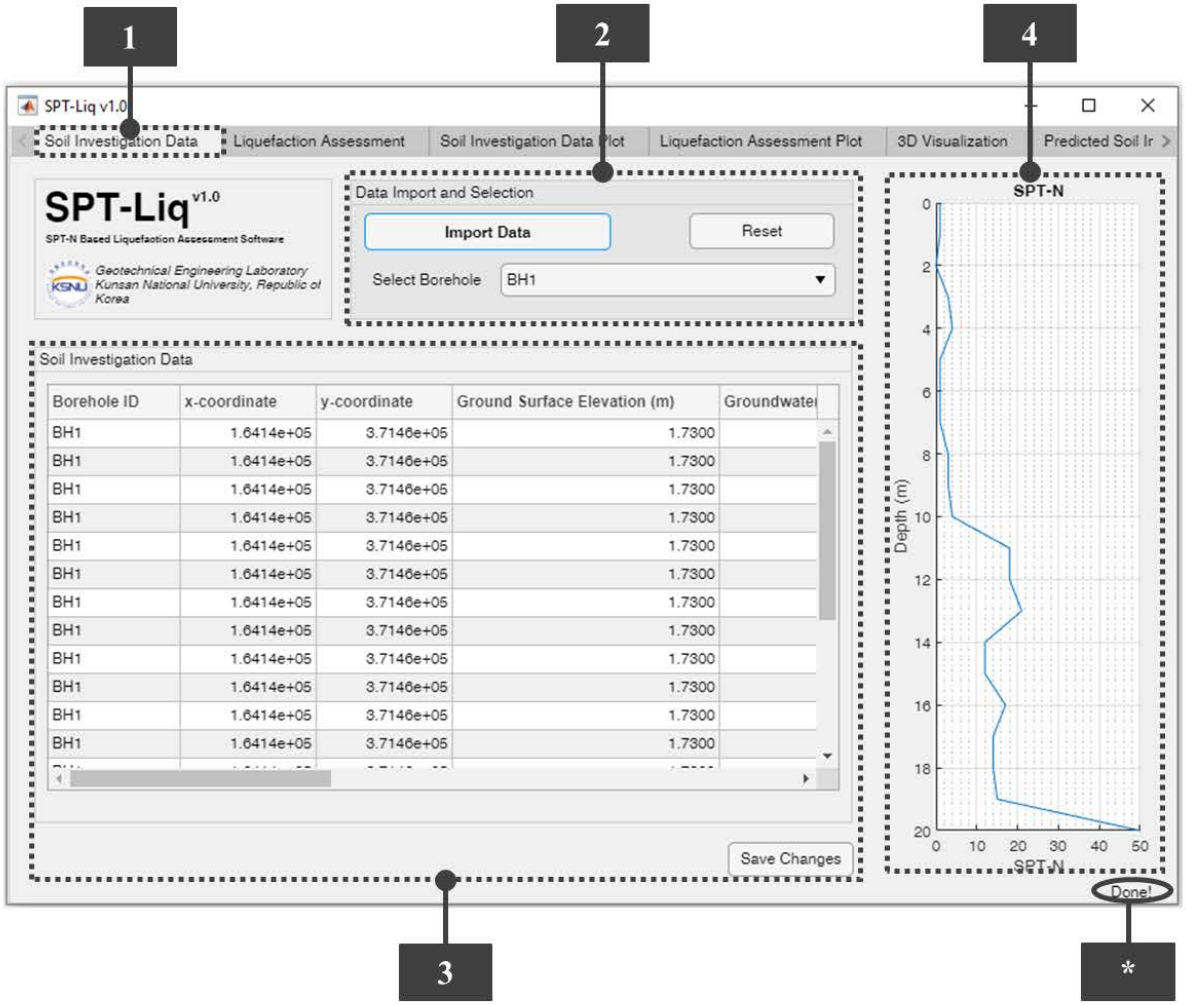


Fig. 3 Soil Investigation Data Tab

○ **Data Import and Selection Panel**

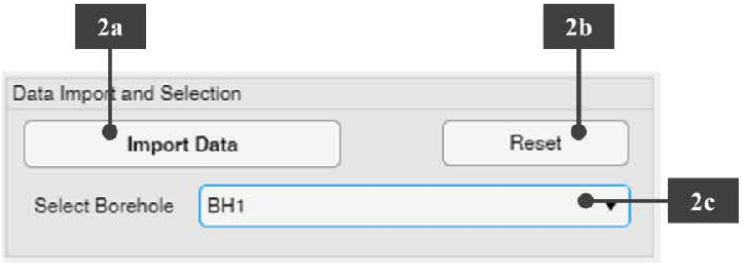


Fig. 4 Data Import and Selection Panel

The "Data Import and Selection Panel" panel [Fig 4] is located at the top part of the "Soil Investigation Data" tab [1]. Initially, the soil investigation data from the boreholes that are going to be analyzed are imported. The imported data has to be written in the excel file and the columns must contain the following variables in order: 1) Borehole ID, 2) x-coordinate, 3) y-

coordinate, 4) Ground Surface Elevation, 5) Groundwater Level, 6) Depth, 7) SPT-N, 8) Soil Type/Classification, 9) Unit Weight, 10) Fines Content (FC), and 11) D50. The unit of distance has to be in meter (m). For variable (9), the unit has to be in kN/m^3, variable (10) in percentage (%), and variable (11) in millimeter (mm). For the imported data, only one value can be assign for every one meter depth from zero to twenty meters. The progress of data import process can be seen from the indicator [*] at the bottom right corner of the table. The indicator will shows "Processing..." while the importing process is still undergoing, and it will shows "Done!" when the process is completed.

The user can change the previously imported soil investigation data by clicking the reset button [2b] and then import the new dataset. The user can select the borehole data to be investigated based on the previously imported data by clicking the data selection button [2c].

○ **Soil Investigation Data Panel**

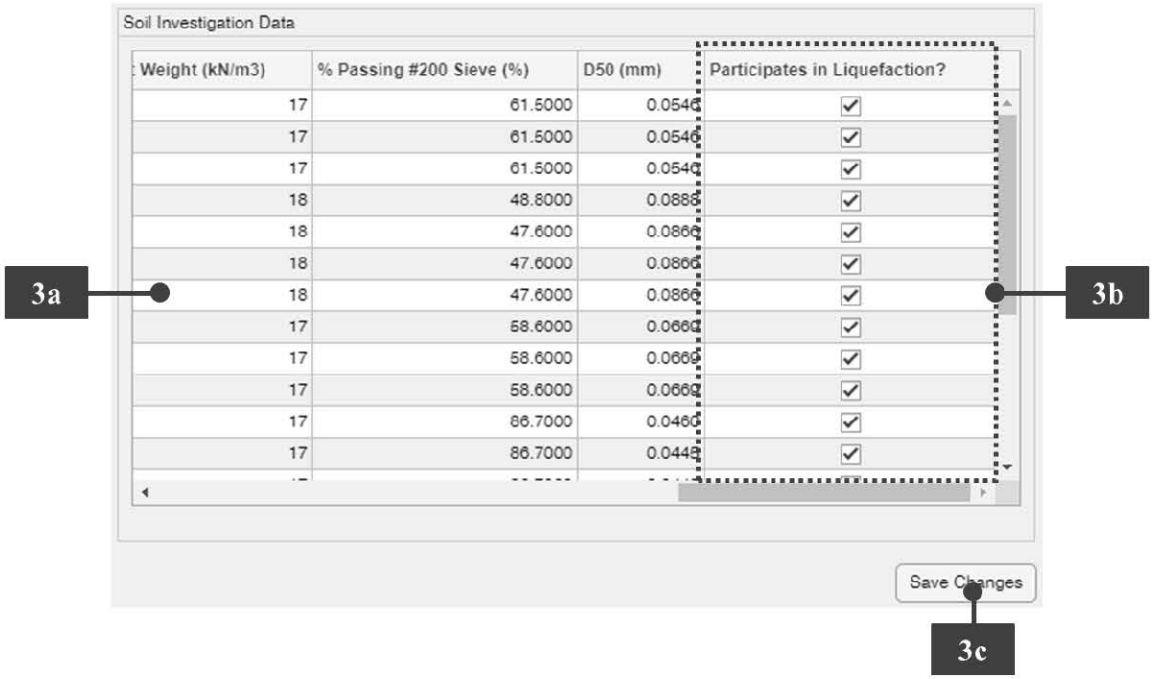


Fig. 5 Soil Investigation Data Panel in Soil Investigation Data Tab

After importing the soil investigation data with the predetermined format, the data will automatically plotted into the table [3a] at the bottom of the tab [1]. For the SPT-N data, the profile will be plotted on graph [4]. At the last column of table [3a], the "Participates in Liquefaction?" column [3b], the user can choose to include or exclude particular soil layers in the liquefaction assessment process. This can be done by checking/unchecking the check box in this column. The user can keep all the changes made in table [3a] by clicking the save changes button [3c].

- **Liquefaction Assessment Tab**

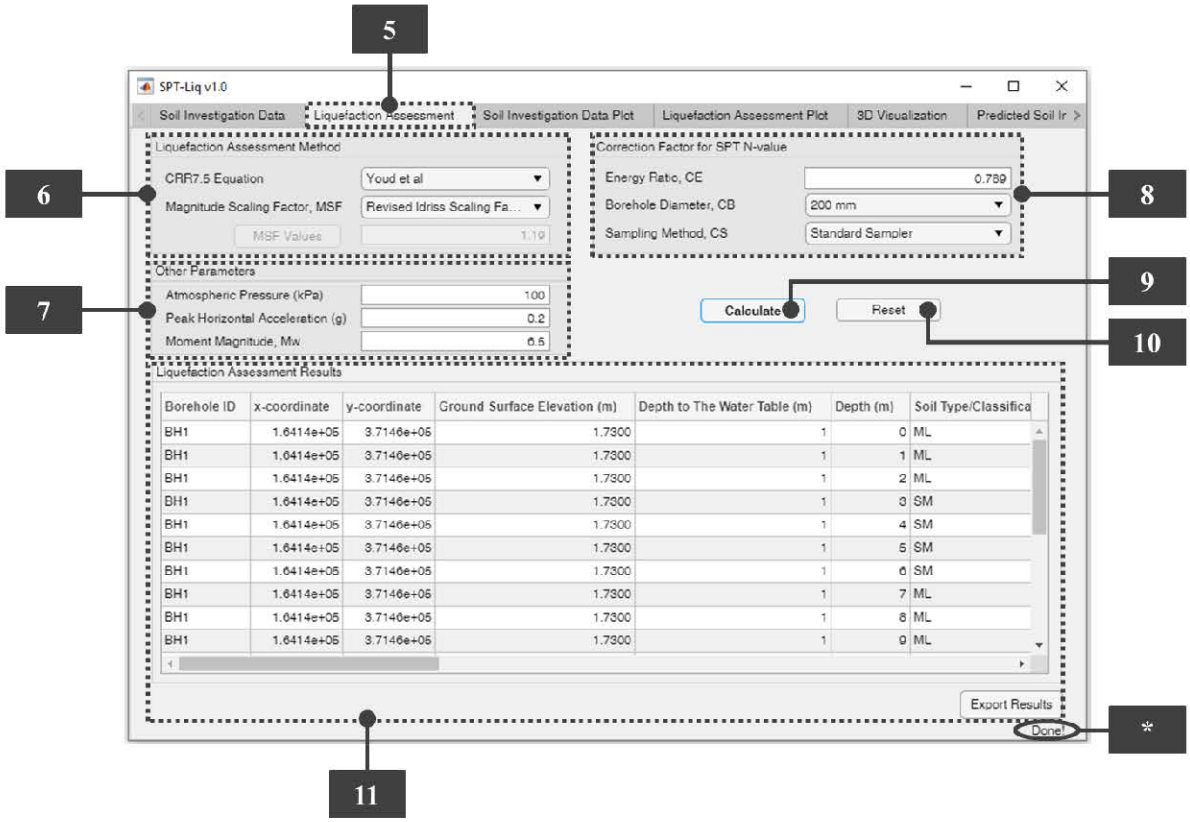


Fig. 6 Liquefaction Assessment Tab

○ **Liquefaction Assessment Method Panel**

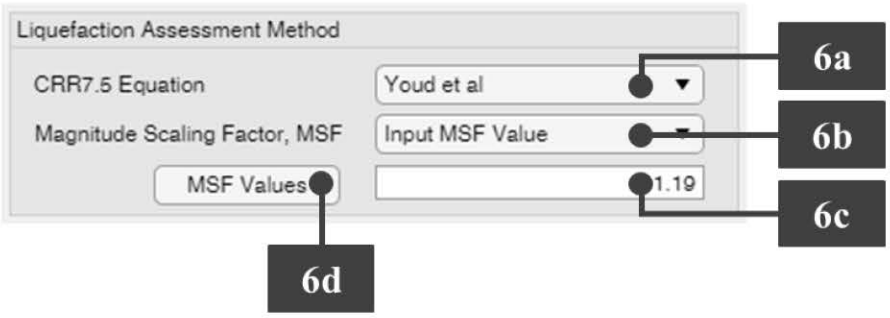


Fig. 7 Input and Selection Panel for Liquefaction Assessment Method

The "Liquefaction Assessment Method" panel [6] is located at the top left part of the "Liquefaction Assessment" tab [5]. There are four options under the "CRR7.5 equation" menu [6a]. This enables the user to choose the preferred method for liquefaction assessment. The next part of this panel are the Magnitude Scaling Factor (MSF) option. This part consists of "Magnitude Scaling Factor, MSF" menu [6b], MSF box [6c], and MSF Values button [6d]. The "Magnitude Scaling Factor, MSF" menu [6d] let the user to choose the MSF, between Revised

Idriss Scaling Factor or input the MSF value manually. If the user choose the first option, the designed moment magnitude (M_w) needs to be inputted into the [7c] box in "Other Parameters" panel [7]. If the user choose the second option, the user can choose the MSF based on the designed M_w, by referring to the provided MSF table available by clicking the "MSF Values" button [6d], and input the chosen MSF value into the box [6c]. The MSF value does not has to be inputted for calculation using "Japan Design Specification on Highway Bridge" and "Korean Liquefaction Assessment Method". The first method does not consider M_w or MSF in the calculation, and for the second method, the Mw and MSF value has been predetermined with 6.5 for the M_w, and 0.84 for the MSF.

○ **Other Properties Panel**

Fig. 8 Input Panel for Other Parameters (Atmospheric Pressure, Peak Horizontal Acceleration and Moment Magnitude)

In this panel, the user can input the atmospheric pressure in kilopascal (kPa), peak horizontal acceleration (g), and moment magnitude (Mw) in the three editable box [7a], [7b], [7c] respectively. The "Moment Magnitude, Mw" box [7c] will only active for liquefaction assessment using Youd et al. method and when the Revised Idriss Scaling Factor is chosen for determining the MSF.

○ **Correction Factor for SPT-N Value Panel**

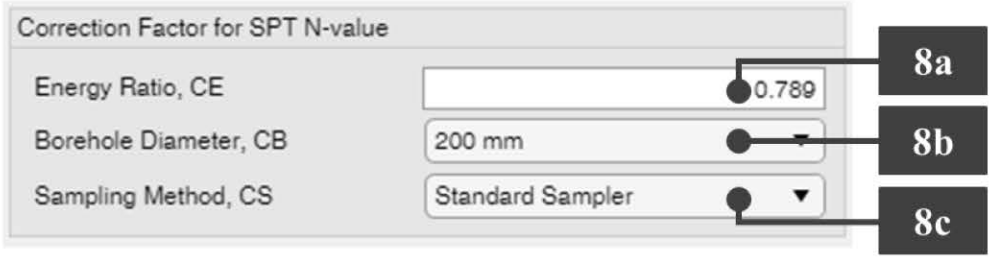


Fig. 9 Correction Factor for SPT N-value Input and Selection Panel

This panel provides the correction factor for the $(N_1)_{60}$ value. There are one editable box [8a]

and two dropdown menu [8b], [8c] in this panel. The user can input the Energy Ratio (CE) factor in the [8a] box. Other correction factors such as Borehole Diameter (CB) and Sampling Method (CS) can be chosen from the dropdown menu [8b] and [8c] respectively.

○ **Calculate and Reset Button**

The user can run the liquefaction assessment calculation by pressing the "Calculate" button [9]. This button will not active if the soil physical properties prediction in the previous tab have not been computed. The reset button [10] will reset all the parameters to the initial values and states.

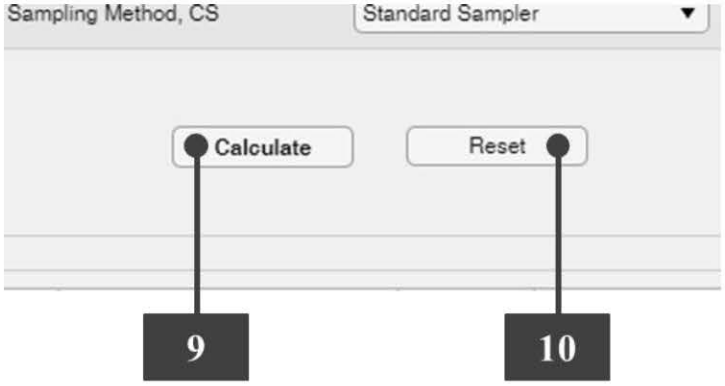


Fig. 10 Calculate and Reset Button in Liquefaction Assessment Tab

○ **Liquefaction Assessment Results Panel**

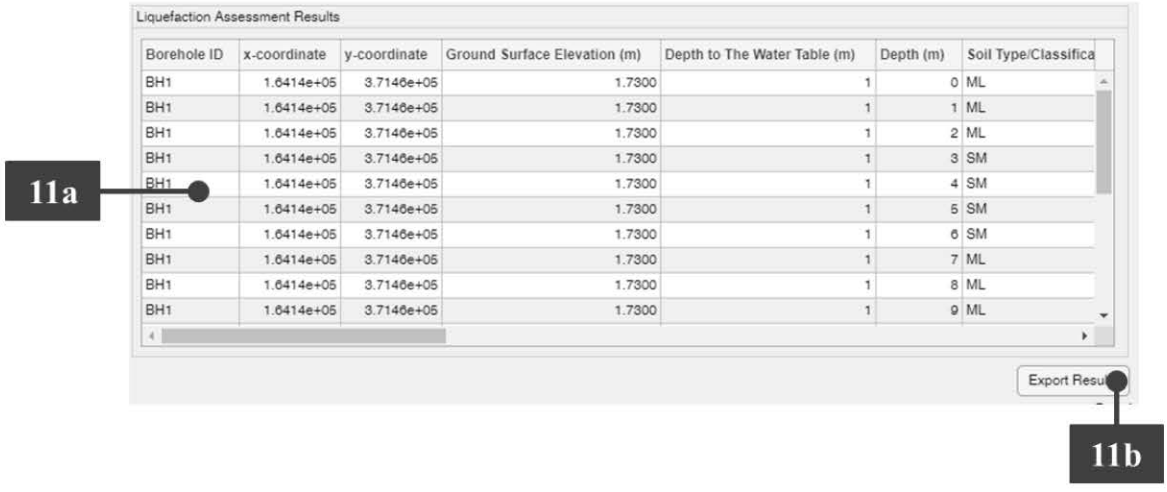


Fig. 11 Liquefaction Assessment Results Panel in Liquefaction Assessment Tab

The liquefaction assessment results are displayed in the "Liquefaction Assessment Results" panel [11] at the bottom side of the tab. The results are displayed in the table [11a], containing the combination of the soil investigation data and properties related to the liquefaction

assessment (stress reduction coefficient (r_d), effective and total vertical stress (σ_v and σ'_v), SPT-N, N60, (N1)60, cyclic stress ratio (CSR), cyclic resistance ratio (CRR), magnitude scaling factor (MSF), factor of safety (FS), F.w(z), and liquefaction potential index (PL)). These results can be exported in to an excel file by clicking the "Export Results" button [11b] at the bottom right of the panel.

- **Soil Investigation Data Plot Tab**

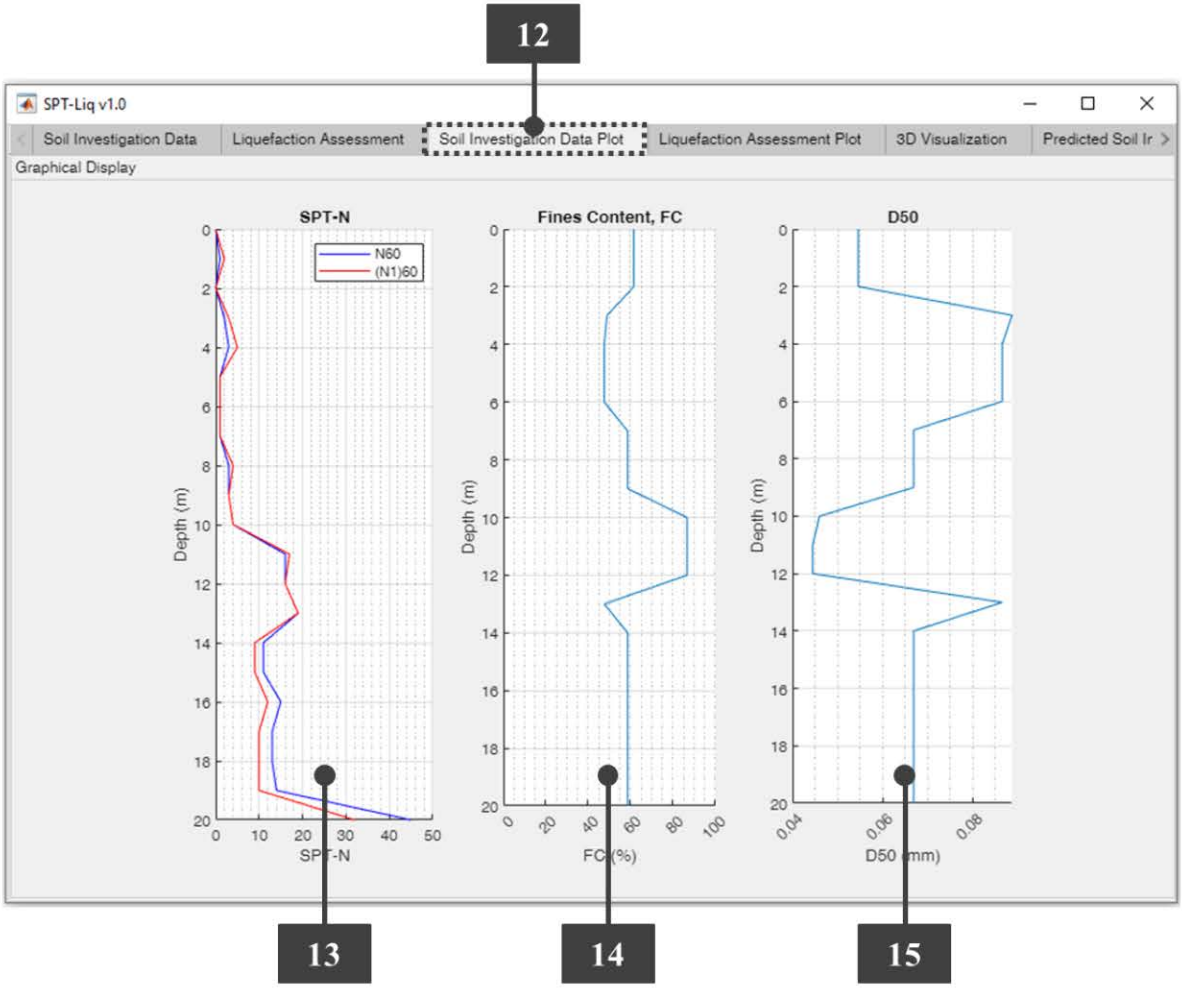


Fig. 12 Soil Investigation Data Plot Tab

Three graphs will be plotted based on the imported soil investigation data from the previous tabs. The SPT-N/N60/(N1)60 value, FC, and D50 profiles will be plotted on graph [13], [14], and [15] respectively within 20 m depth. The graphs are displayed in the "Graphical Display" Panel at the "Soil Investigation Data Plot" tab [12].

- **Liquefaction Assessment Plot Tab**

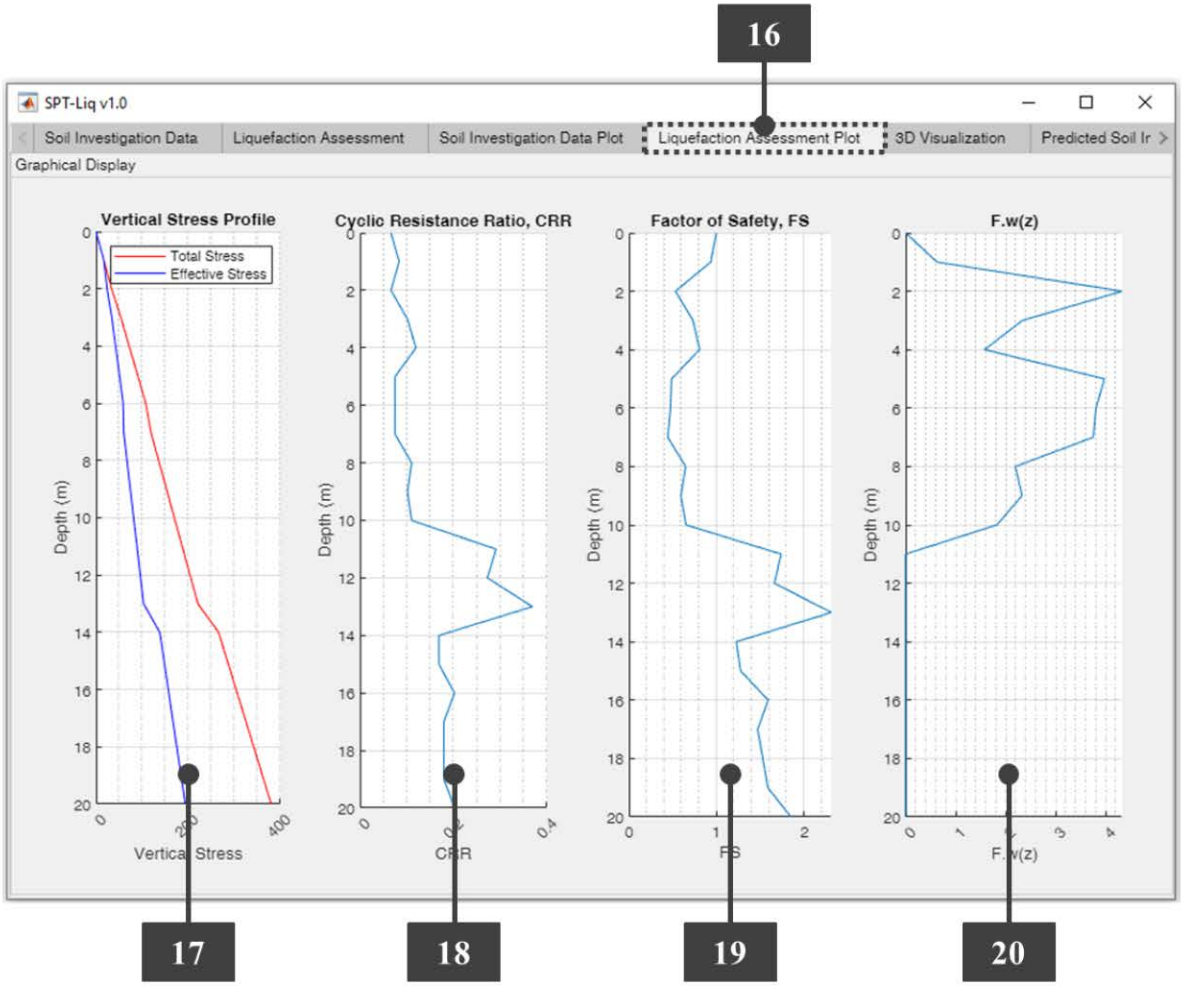


Fig. 13 Liquefaction Assessment Plot Tab

The liquefaction assessment results are displayed in the "Graphical Display" panel at the "Liquefaction Assessment Plot" tab [16]. Four graphs will be plotted based on the previous liquefaction assessment. The rightmost graph [17] presents the total and effective vertical stress profile, while the middle graphs [18] and [19] present the calculated CRR and FS within within 20 m depth. The rightmost graph displays the F.w(z) value, where the summation of these values is equal to the Liquefaction Potential Index (LPI).

- **3D Visualization Tab**

This software features three-dimensional visualization of the liquefaction hazard and soil physical properties prediction in the form of surface plot. The user can choose the properties to be visualized by selecting the options in the dropdown menu [22] in the "3D Visualization" Tab [21].

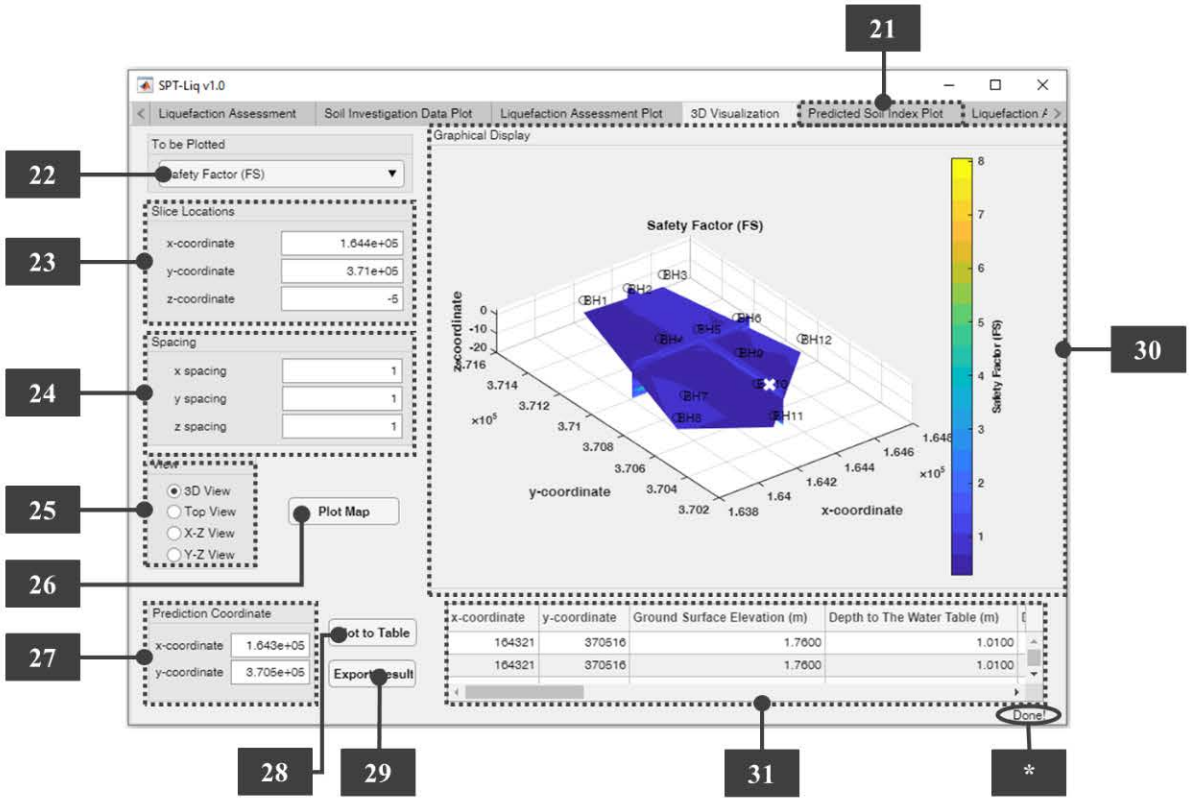


Fig. 14 3D Visualization Tab

The user can create a slice plane orthogonal to the x-, y-, and z- axis by inputting the x-, y-, and z-coordinate location into box [23a], [23b], and [23c] to determine the slice plane locations. The interpolation spacing can be set by inputting the value for the x-, y-, and z-axis into the box [24a], [24b], and [24c] respectively in the "Spacing" panel [24]. The user is also able to pinpoint a location to get the predicted properties on that specific location, simply by inputting the x- and y- coordinate into the box [27a] and [27b] respectively in the "Prediction Coordinate" panel [27]. The "View" panel [25] allows the user to select and switch the plotting plane of the generated map by selecting the available options.

To start the map generation process, the user can click the "Plot Map" button [26]. Indicator [*] located at the bottom right of the tab will tell the user whether the map generation process is undergoing or has been done. The results will be displayed in the form of interactive plot in the graphical display [30]. By clicking the "Plot Table" button [28], the predicted properties at the previously determined point (panel [27]) will be displayed in the table [31]. The predicted value can be exported into an excel file by selecting the "Export Results" button [29].

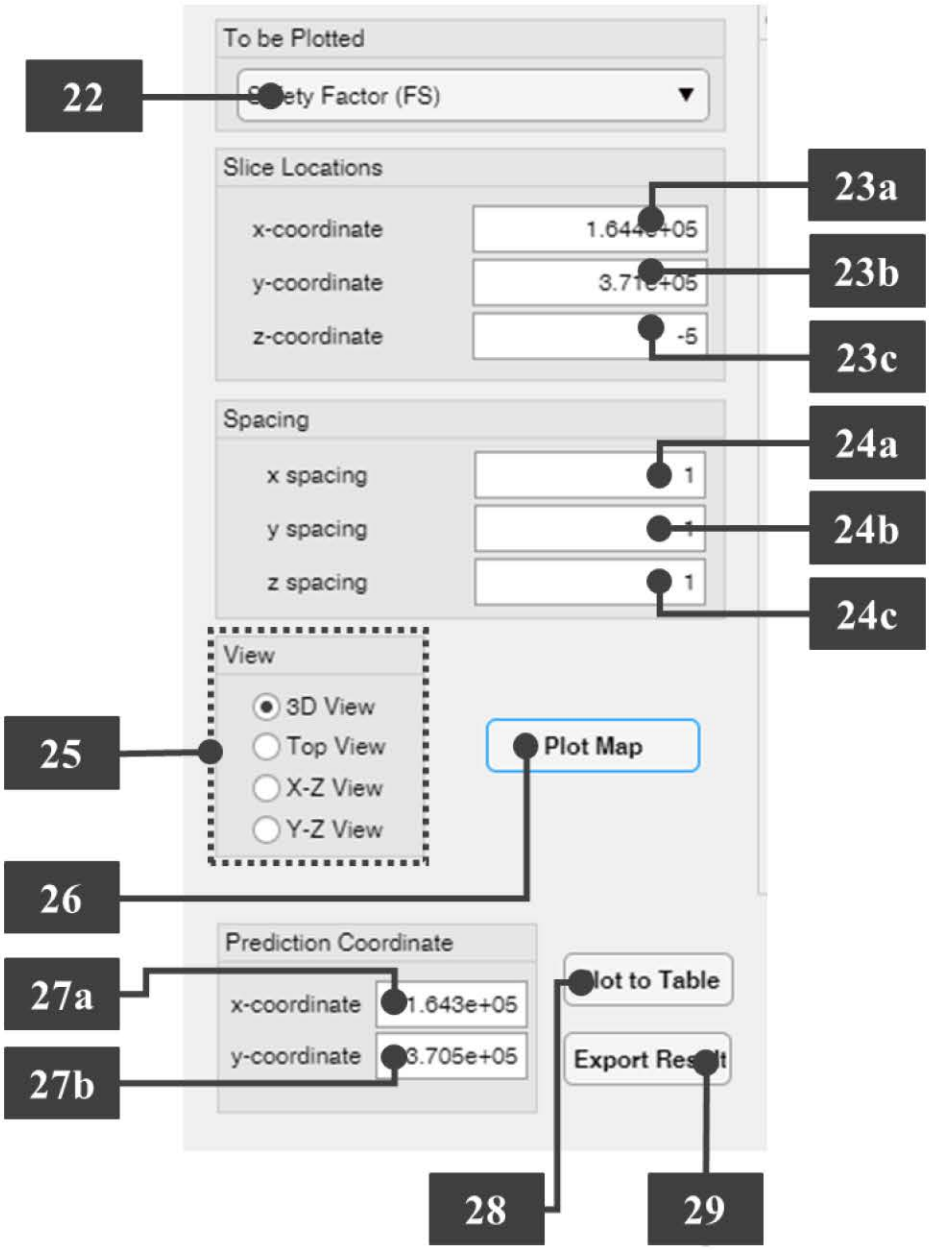


Fig. 15 Input Panels, Selection Panels, and Push Buttons in 3D Visualization Tab

Particularly for "Safety Factor (FS)" and "Liquefaction Potential (PL)", the prediction results will depend on the liquefaction assessment method and other properties inputted or selected by the user in the "Liquefaction Assessment" tab [5].

- **Predicted Soil Index Plot Tab**

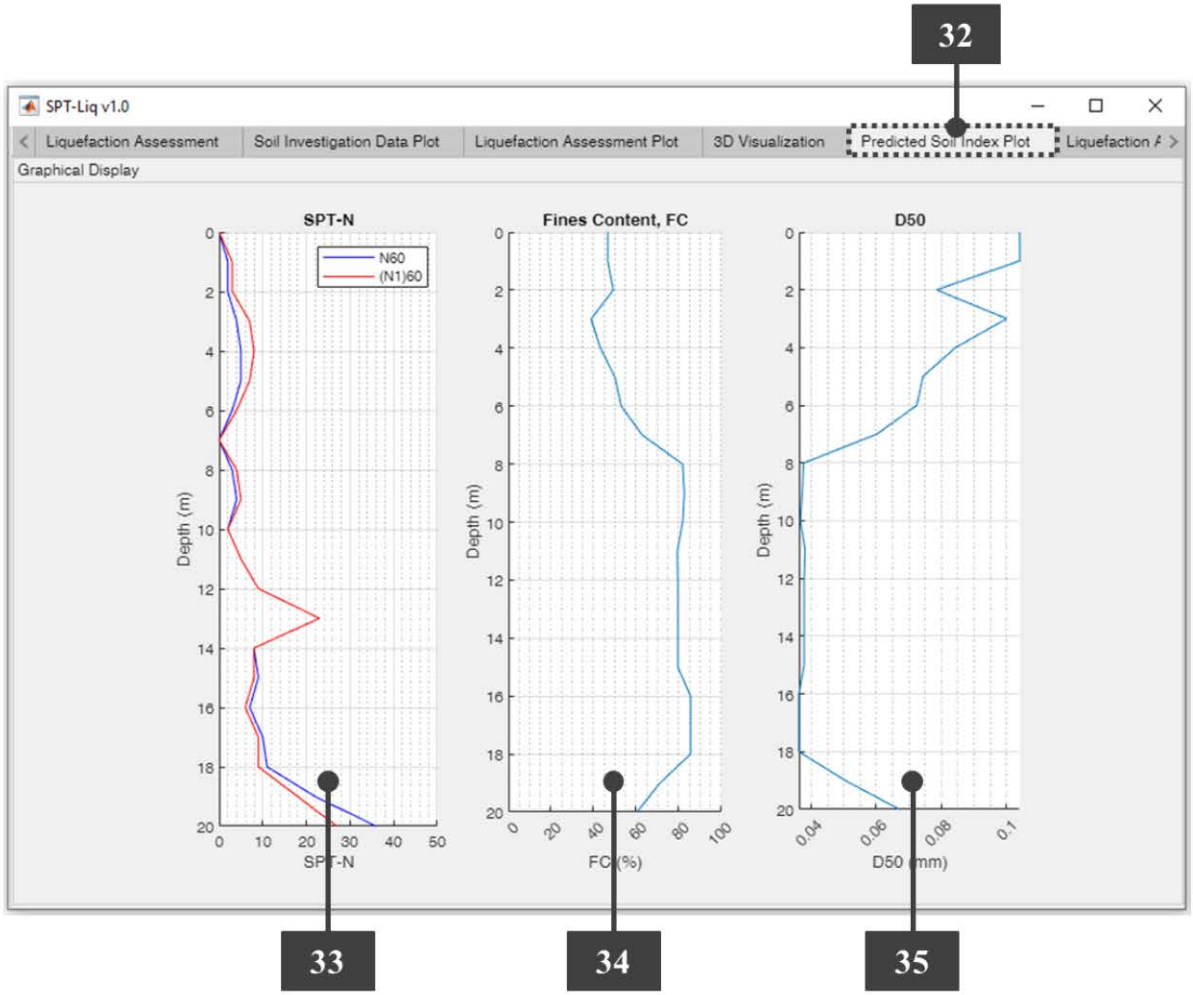


Fig. 16 Predicted Soil Index Plot Tab

Three graphs will be plotted based on the predicted soil properties from the previous tabs. The predicted SPT-N/N60/(N1)60 value, FC, and D50 profiles will be plotted on graph [33], [34], and [35] respectively within 20 m depth. The graphs are displayed in the "Graphical Display" Panel at the "Predicted Soil Index Plot" tab [32].

- **Liquefaction Assessment Plot (Prediction)**

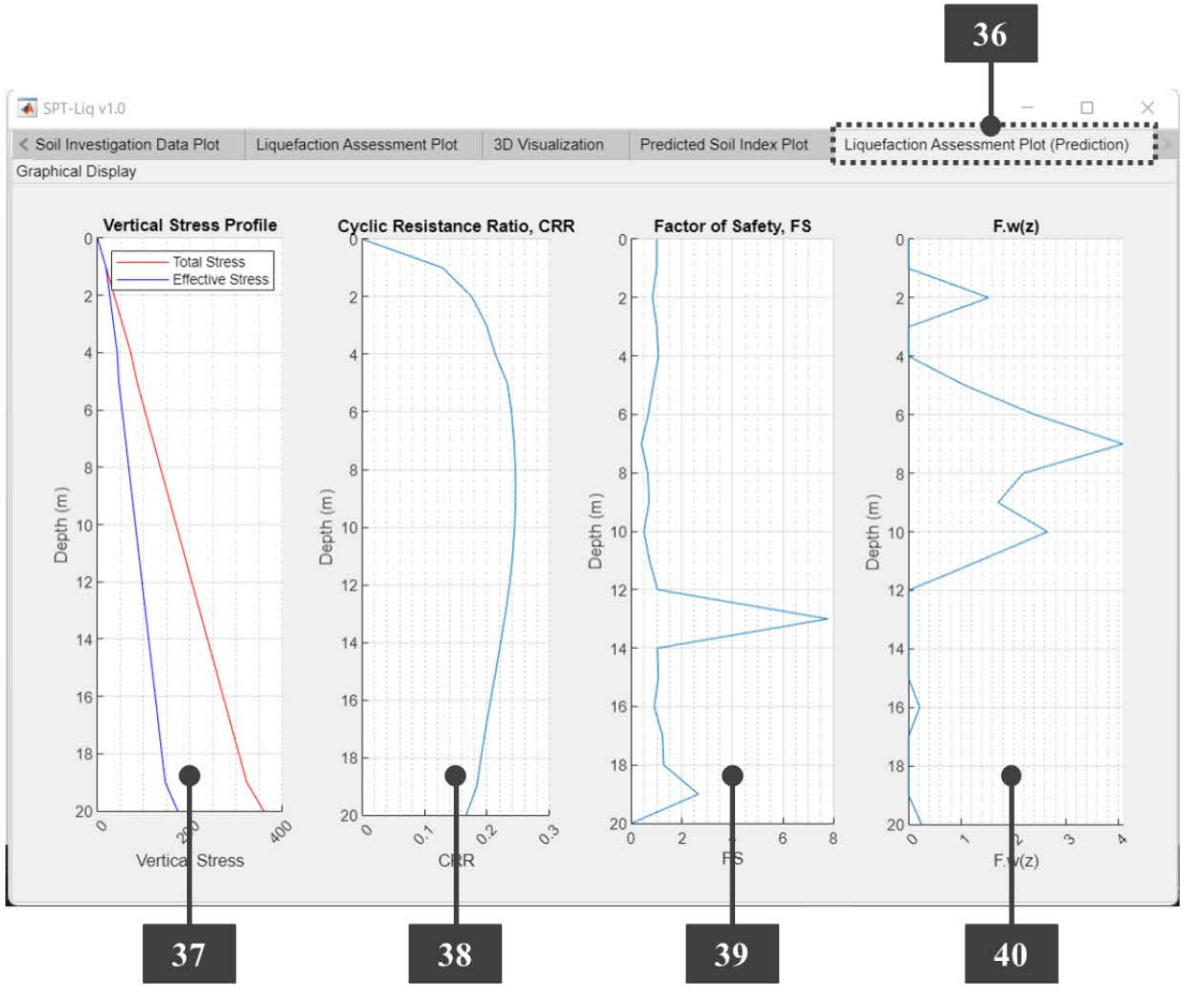


Fig. 17 Liquefaction Assessment Plot (Prediction) Tab

The liquefaction assessment results from the predicted soil properties are displayed in the "Graphical Display" panel at the "Liquefaction Assessment Plot (Prediction)" tab [36]. Four graphs will be plotted based on the previous liquefaction assessment. The rightmost graph [37] presents the total and effective vertical stress profile, while the middle graphs [38] and [39] present the calculated CRR and FS within 20 m depth. The rightmost graph displays the F.w(z) value, where the summation of these values is equal to the Liquefaction Potential Index (LPI).

Step-by-step Guide

Notes

- Run the installer and select the installation location
- Run the application as an administrator
- The exported tables and graphs will be saved at the same folder as the launched "SPTLiq.exe".

Soil Investigation Data Tab

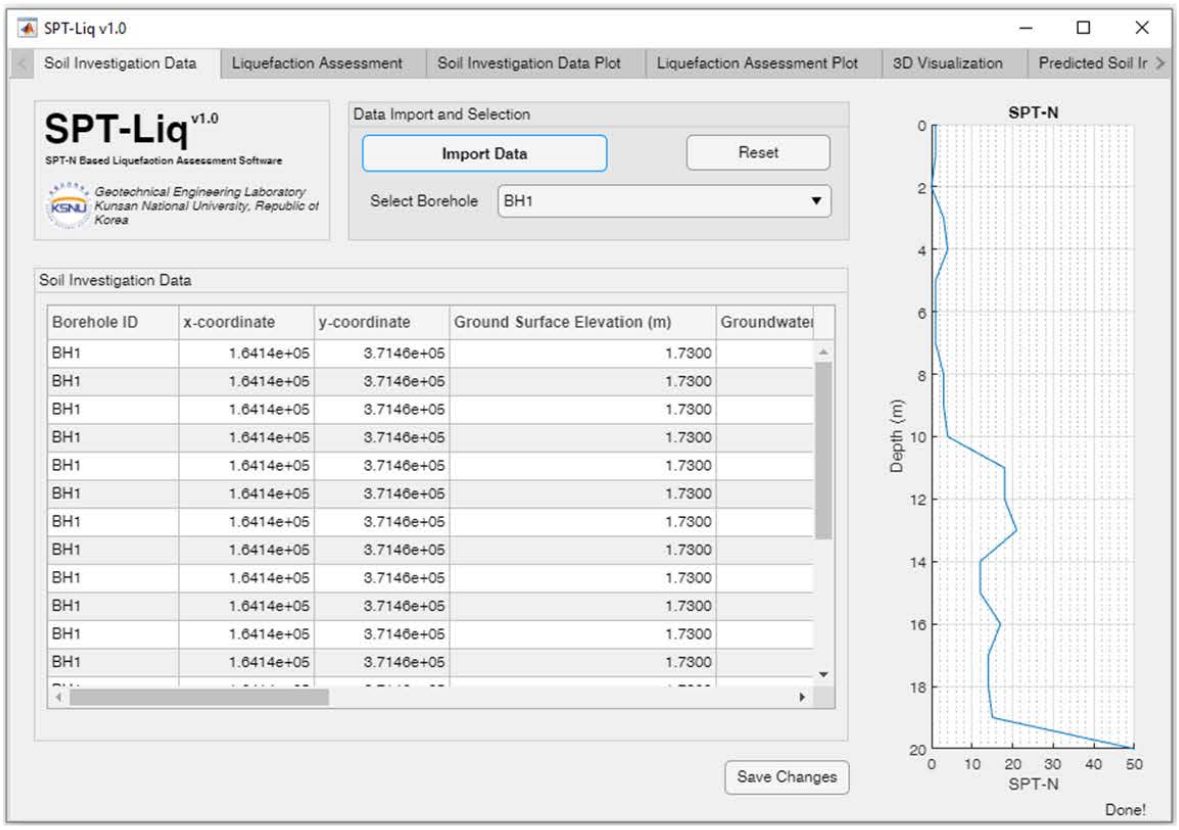
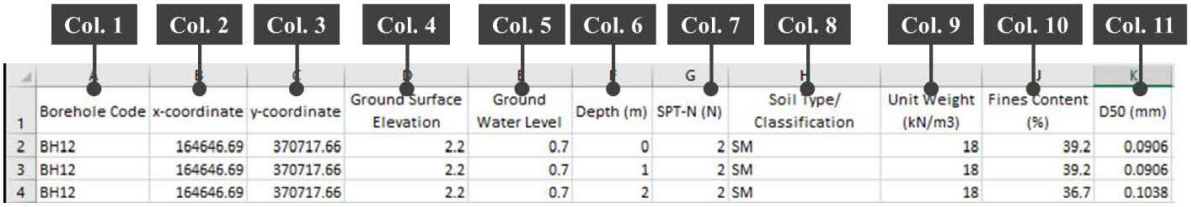


Fig. 18 Soil Investigation Data Tab

- (Data Entry) In SPT-Liq v1.0, the soil investigation data that need to be imported by the user are explained below:
- The imported data must be in the excel file format.
- The excel file have to be in this following format:
- First row has to contains the variables name and the following rows contain the soil investigation data
- The variables name written in the first row of the excel file can be anything. However, the data must follow this specific order:



	A	B	C	D	E	F	G	H	I	J	K
1	Borehole Code	x-coordinate	y-coordinate	Ground Surface Elevation	Ground Water Level	Depth (m)	SPT-N (N)	Soil Type/ Classification	Unit Weight (kN/m3)	Fines Content (%)	D50 (mm)
2	BH12	164646.69	370717.66	2.2	0.7	0	2	SM	18	39.2	0.0906
3	BH12	164646.69	370717.66	2.2	0.7	1	2	SM	18	39.2	0.0906
4	BH12	164646.69	370717.66	2.2	0.7	2	2	SM	18	36.7	0.1038

Fig. 19 Soil Investigation Data Tab

- The first column must contain the ID for the borehole. The code can be numerical, character, or combination of both.
- The second column must contain the x-coordinate of the borehole. The coordinate unit must be in meter.
- The third column must contain the y-coordinate of the borehole. The coordinate unit must be in meter.
- The fourth column must contain the ground surface elevation, with the unit in meter.
- The fifth column must contain the groundwater level (elevation), with the unit in meter.
- The sixth column must contain the depth of the observed soil, where the unit should be in meter and the data have to be inputted for every meter from zero to twenty meter depth.
- The seventh until the eleventh (last) column must contain the recorded SPT-N value, soil type/classification, unit weight of soil, fines content (FC), and D50 for every meter depth from zero to twenty meter.

- The imported soil investigation data are listed in the "Select Borehole" dropdown menu. The user can choose the borehole data to be assessed by choosing the borehole code exist in this dropdown menu. The soil investigation data of the selected borehole will be displayed in the "Soil investigation Data" table.
- In the next step, the user needs to determine whether the soil layer will be considered in the liquefaction assessment or not. This can be done by checking or unchecking the check box at the last column of the table. The changes made can be saved by clicking the save changes button at the bottom of the tab.
- The user can click the reset button to reset the state of all tabs to their initial state.

Liquefaction Assessment, Soil Investigation Data Plot, and Liquefaction Assessment Plot Tab

- This tab allows the user to choose the preferred method and to set the parameters to perform the liquefaction assessment. The liquefaction assessment in this tab will only be done to the selected borehole in the previous tab.
- Four commonly known methods are available to be chosen by the user. Please refer to the

references to set the suitable value for the parameters in this tab.

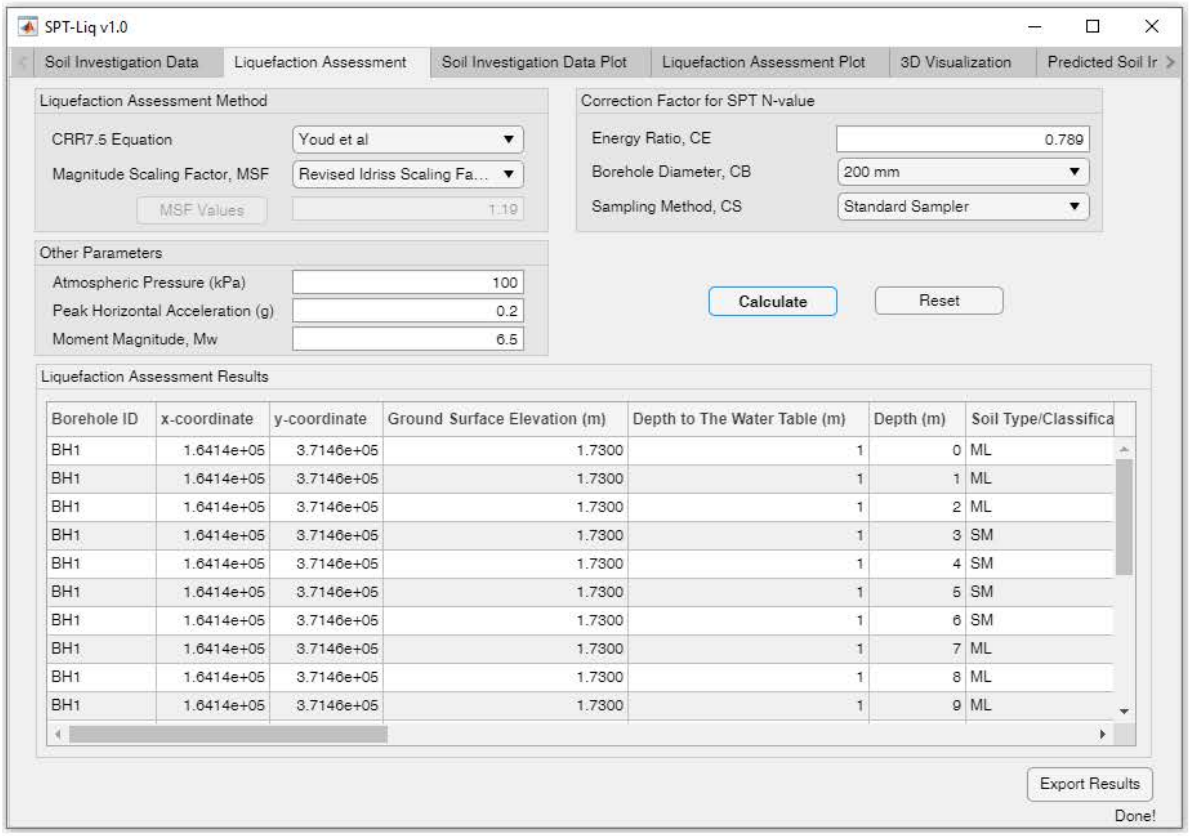


Fig. 20 Liquefaction Assessment Tab

- After choosing the method and set the suitable parameters, the user can start the liquefaction assessment process by clicking the calculate button. The results will be displayed in the "Liquefaction Assessment Results" table at the bottom of the tab. Besides, the SPT-N/N60/(N1)60 value, FC, and D50 profiles will be plotted in the "Soil Investigation Data Plot", and the total and effective vertical stress, CRR, FS, and the F.w(z) profile will be plotted in the "Liquefaction Assessment Plot" tab.
- Liquefaction assessment results can be exported into an excel file and figures by clicking the export results button. The exported results will be saved inside a dedicated folder for each assessed borehole.
- The user can reset the state of this "Liquefaction Assessment" tab by clicking the reset button.

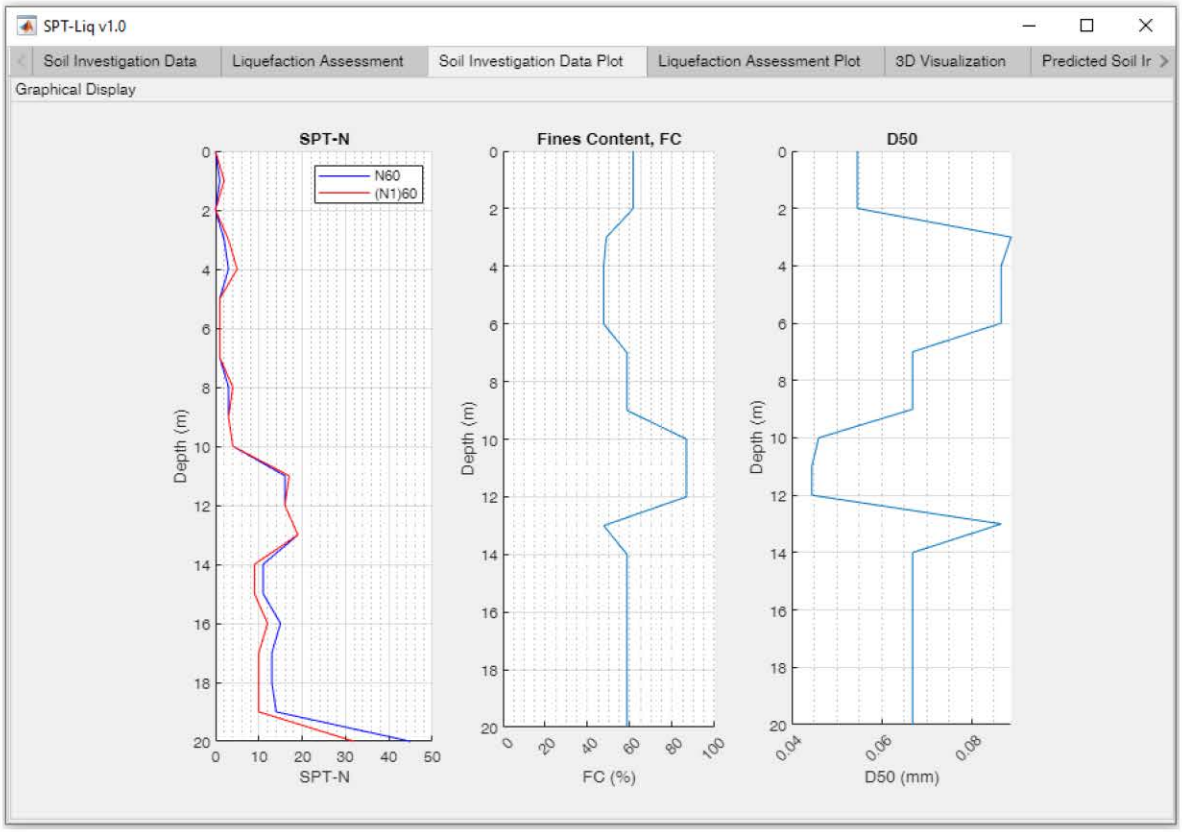


Fig. 21 Soil Investigation Data Plot Tab

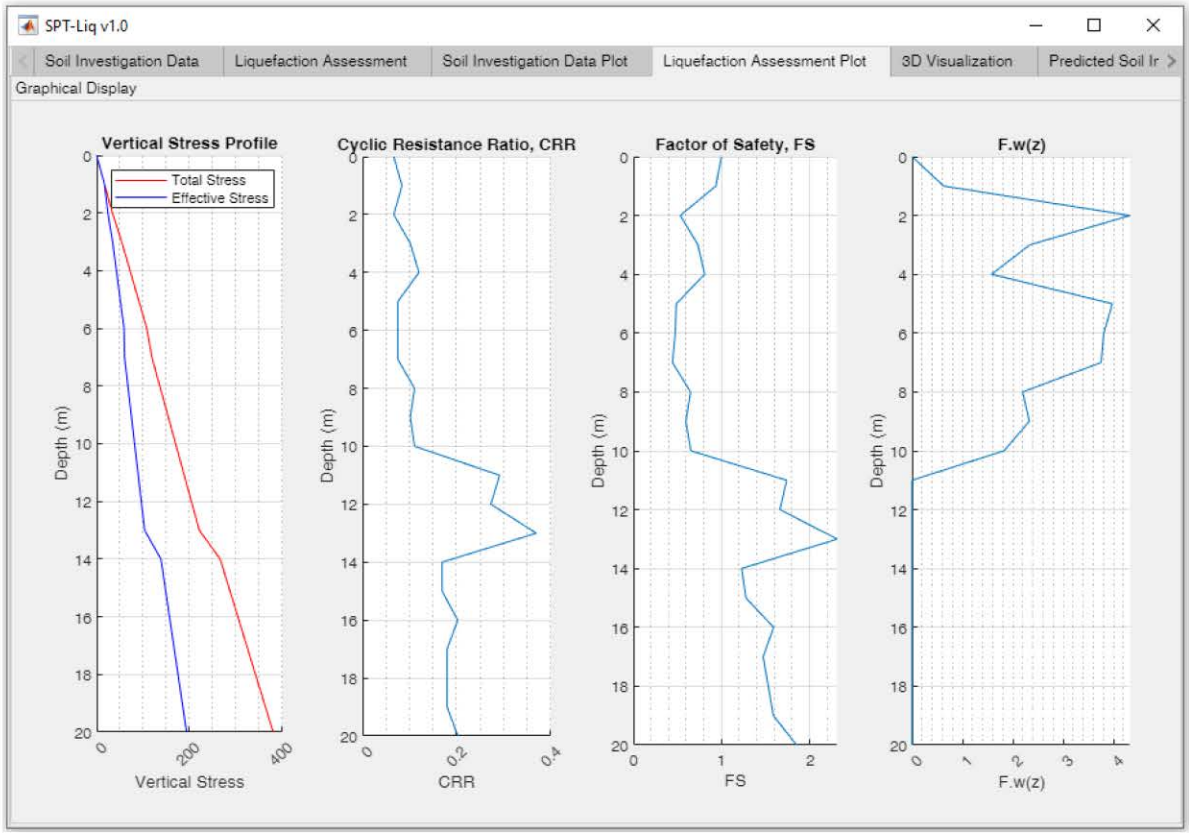


Fig. 22 Liquefaction Assessment Plot Tab

3D Visualization, Predicted Soil Index Plot, and Liquefaction Assessment Plot (Prediction) Tab

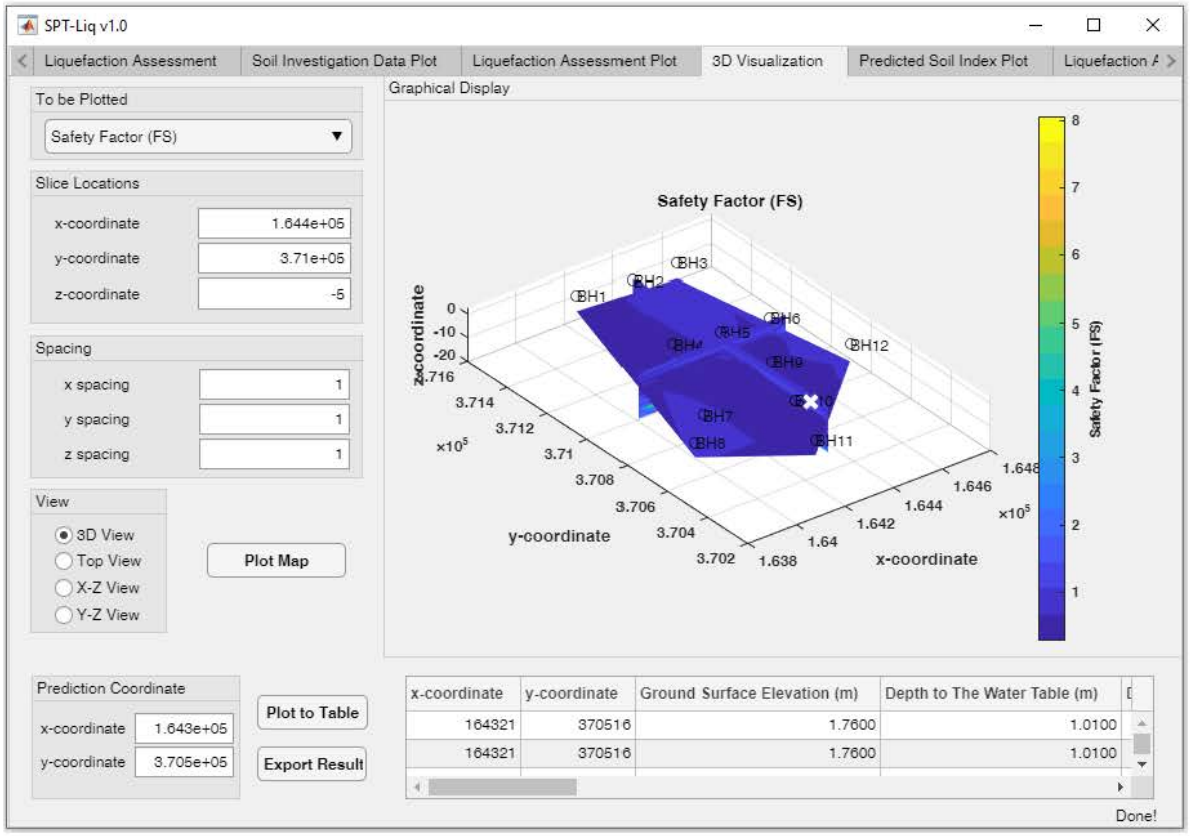


Fig. 23 3D Visualization Tab

- SPT-Liq v1.0 provides three-dimensional mapping of predicted soil properties and liquefaction hazard. The user can set some settings for the 3D visualization of the map in the "3D Visualization" tab:
- The user is able to choose which type of predicted data to be plotted. There are eight options under the dropdown menu in the "To be Plotted" panel for the user to choose:
  1) Ground Surface Elevation
  2) Groundwater Level
  3) SPT-N
  4) Soil Type
  5) % Passing #200 Sieve
  6) D50
  7) Safety Factor (FS)
  8) Liquefaction Potential (PL)
- The user is able to generate a slice plane orthogonal to the x-, y-, and z- axis for option (3), (4), (5), (6), and (7). This can be done by inputting the x-, y-, and z-coordinate location into the field box in the "Slice Location" panel to determine the slice plane locations. **The slice plane**

location has to be inside the interpolation area. This feature has no effect on the plotting of option (1), (2), and (3).

- The "Spacing" panel allows the user to input the desired interpolation spacing. Smaller spacing will results in smoother surface and longer processing time.
- The user can choose the options available in the "View" panel to change the line of sight of the map. This panel will be disabled for the option (8).
- The user can specify a location for the analysis. This can done by inputting the x- and y-coordinate into the "Prediction Coordinate" panel. **The specified location has to be inside the interpolation area.**
- Click the "Plot Map" button to start the map plotting process. After clicking the button, a white cross will be plotted inside the "Graphical Display" panel, which indicates the specified location.
- By clicking the "Plot to Table" button, the predicted geotechnical soil properties and liquefaction assessment at the specified location will be displayed in the table at the bottom of the tab. The "Export Result" button allows the user to export the table into an excel files and export the figures displayed in the "Predicted Soil Index Plot" and "Liquefaction Assessment Plot (Predicted)" tab.
- The predicted SPT-N/N60/(N1)60 value, FC, and D50 profiles will be plotted in the "Predicted Soil Index Plot", and the total and effective vertical stress, CRR, FS, and the F.w(z) profile at the specified location will be plotted in the "Liquefaction Assessment Plot (Predicted)" tab.

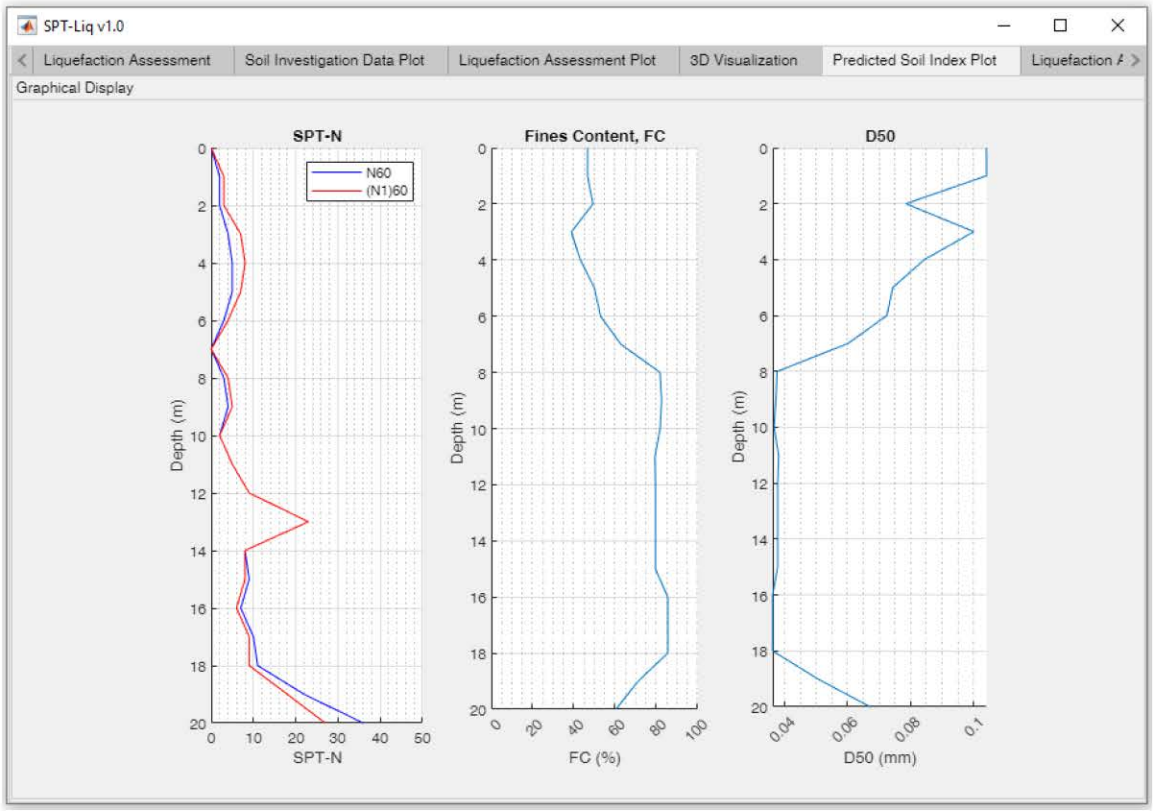


Fig. 24 Predicted Soil Index Plot Tab

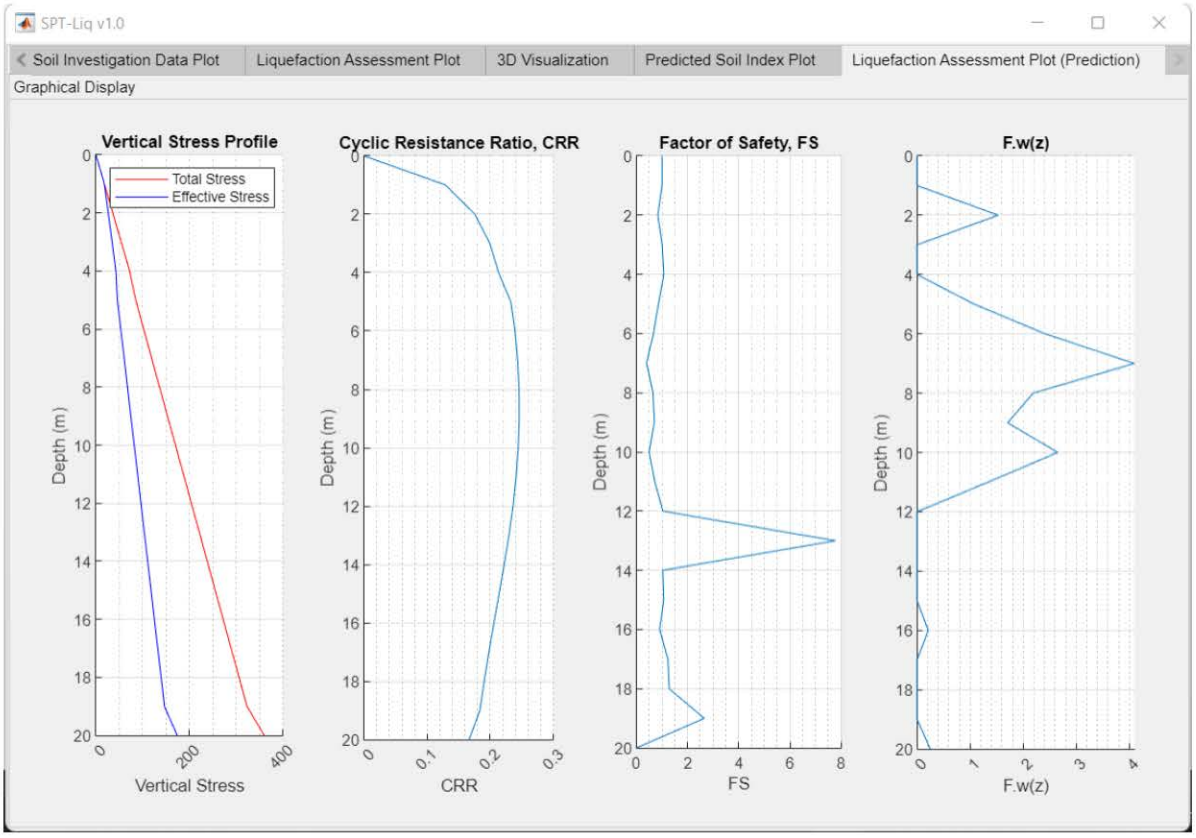


Fig. 25 Liquefaction Assessment Plot (Prediction) Tab

References

① Youd, T. & Idriss, I. & Andrus, Ronald & Arango, Ignacio & Castro, Gonzalo & Christian, John & Dobry, Richardo & Finn, Liam & Jr, Leslie & Koester, Joseph & Liao, Sam & Marcuson, William. (2001). Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshops on Evaluation of Liquefaction Resistance of Soils. Journal of Geotechnical and Geoenvironmental Engineering. 127. 10.1061/(ASCE)1090-0241(2001)127:10(817).

② Choi, J.-S. (2021). Application and Verification of Liquefaction Potential Index in Liquefaction Potential Assessment of Korean Port and Harbor. Journal of the Korean Geotechnical Society , 37 (5), 33–46. https://doi.org/10.7843/KGS.2021.37.5.33

③ Myoung Jin Lee;Woo Jung Choi;Su Ran Kim;Keum Ho Oh. (2019). Policy Recommendations on Support Measures for Liquefaction - Comparison between Korea and Japan -. 한국위기관리논집, 15(6), 31-44.