



# User manual

## Index Properties of Soil

### Version 1

Index Properties Calculator v.1.2025 (@Gutiérrez-Ch, José G.)

### Three-phase Model

**Inputs:**

Weights (N)		Volumes (cm3)	
Wt (N)	1.00	Vt (cm3)	1.00
Wa (N)	1.00	Vv (cm3)	1.00
Ww (N)	1.00	Vw (cm3)	1.00
Ws (N)	1.00	Vs (cm3)	1.00

$W_t$  = Total weight of given soil sample  
 $W_a$  = Weight of air in the voids  $\cong 0$   
 $W_w$  = Weight of water in the voids  
 $W_s$  = Weight of solids  
 $V_t$  = Total volume of soil sample  
 $V_a$  = Volume of air in the voids  
 $V_w$  = Volume of water in the voids  
 $V_s$  = Volume of solids  
 $V_v$  = Volume of voids: air + water (partially saturated soil), water only (saturated soil), air only (dry soil)

Off  On  Activate this option to use weights and volumes as input data. otherwise, enable it to enter index properties instead

**Index properties** Calculate Reset

Dry unit weight, $\gamma_d$ (kN/m <sup>3</sup> )	0.00	Void ratio, e	0.00	Off <input type="checkbox"/> On <input type="checkbox"/>
Bulk unit weight, $\gamma_h$ (kN/m <sup>3</sup> )	0.00	Porosity, n	0.00	
Saturated unit weight, $\gamma_{sat}$ (kN/m <sup>3</sup> )	0.00	Degree of saturation, $S_r$ (%)	0.0	Off <input type="checkbox"/> On <input type="checkbox"/>
Submerged unit weight, $\gamma'$ (kN/m <sup>3</sup> )	0.00	Water content, w (%)	0.0	
	Unit weight of soil solids, $\gamma_s$ (kN/m <sup>3</sup> )	0.00		
	Specific gravity, $G_s$	0.00	Off <input type="checkbox"/> On <input type="checkbox"/>	

Note: This application was developed for academic, non-commercial purposes. For any errors, feedback, or suggestions, please contact me via email.

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**Inputs**  
 1) e  
 2) e,  $G_s$   
 3) e,  $G_s$ ,  $S_r$

**Outputs**  
 1) n  
 2) n,  $\gamma_d$ ,  $\gamma_s$ ,  $\gamma_{sat}$ ,  $\gamma'$   
 3) n,  $\gamma_d$ ,  $\gamma_s$ ,  $\gamma_{sat}$ ,  $\gamma'$ ,  $\gamma_h$ , w

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June 2025

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<https://blogs.upm.es/gutierrez-ch/apps/>



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## 1 Introduction

### 1.1 What is the Index Properties of Soil App?

It is an application developed as a support tool to undergraduate students of the Soil and Rock Mechanics course at the UPM's Civil Engineering Degree (E.T.S.I. de Caminos, Canales y Puertos). The app allows users to quickly obtain index soil properties and compare the results with the exercises proposed in the course.

### 1.2 Who is the App for?

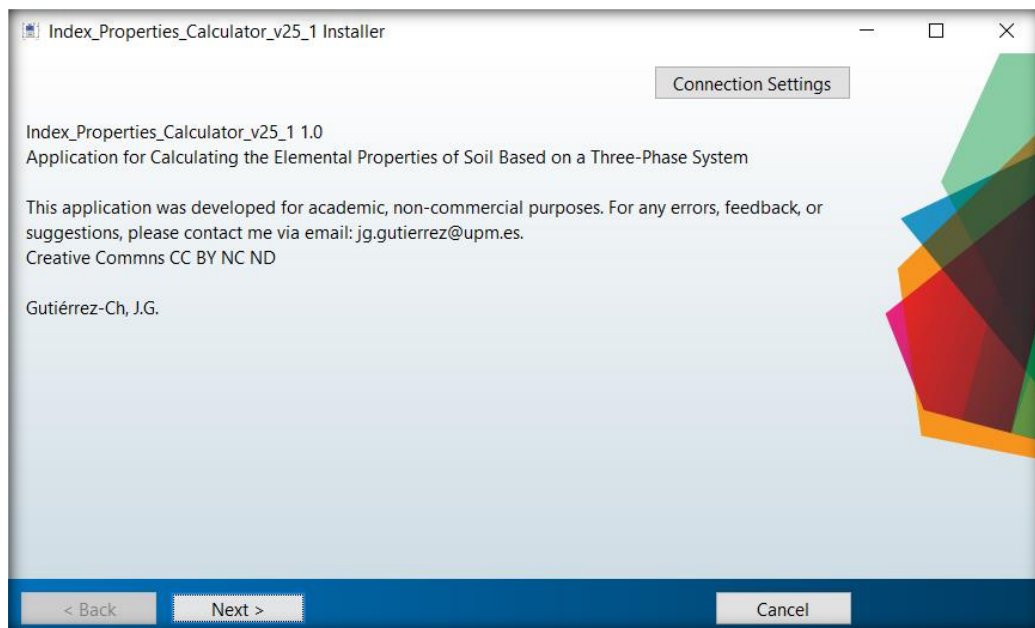
The application is intended for:

- Undergraduate students of the Soil and Rock Mechanics course at the UPM's Civil Engineering Degree.
- Students of other courses related to soil mechanics and geotechnical engineering.
- Professionals in the field of soil mechanics and geotechnical engineering.

### 1.3 Installation steps

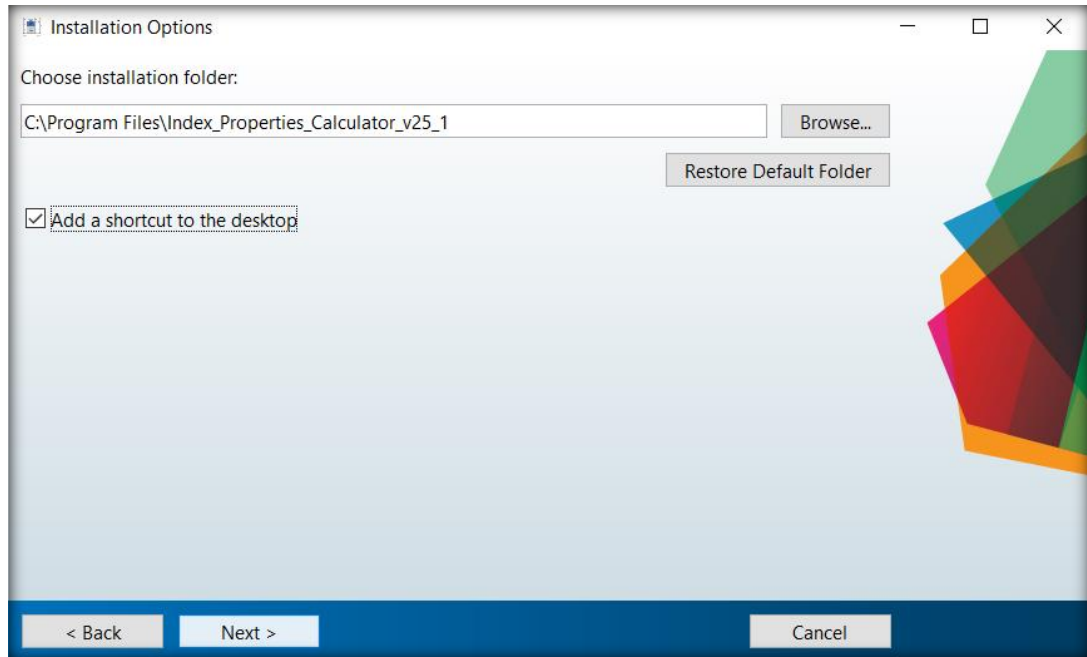
a) Run the file "MyAppInstaller\_web.exe".

b) In the following window, click on "Next" button:

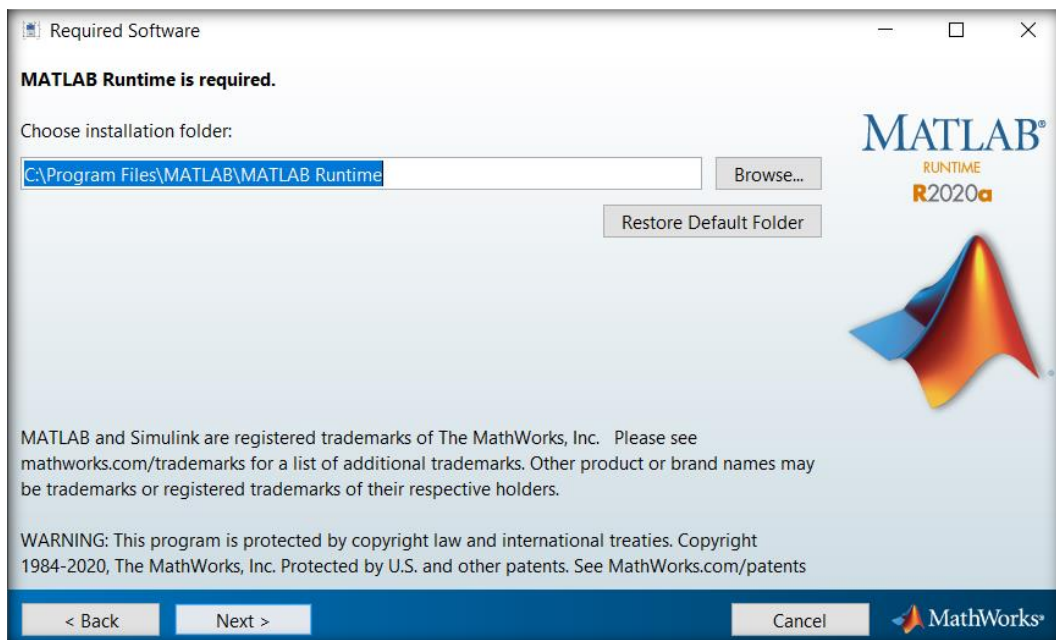


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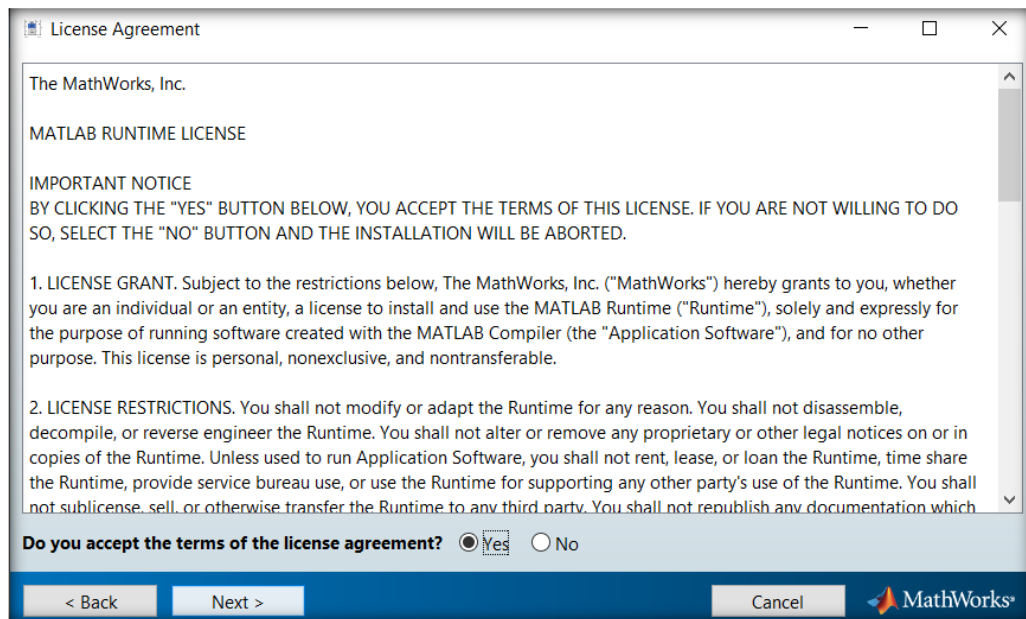
c) Select the folder where you want to install the App. Then, click on “Next” button to confirm your selection and move forward with the installation process. *Tip:* Add a shortcut to a desktop to make accessing the application quicker and more convenient.



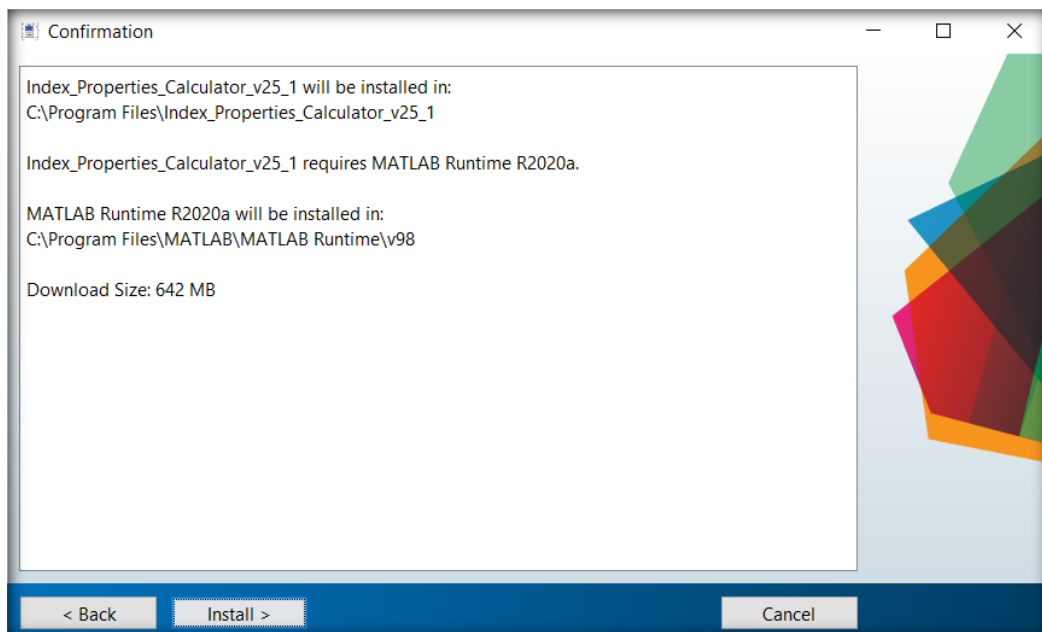
d) In the following window, click on “Next” button:



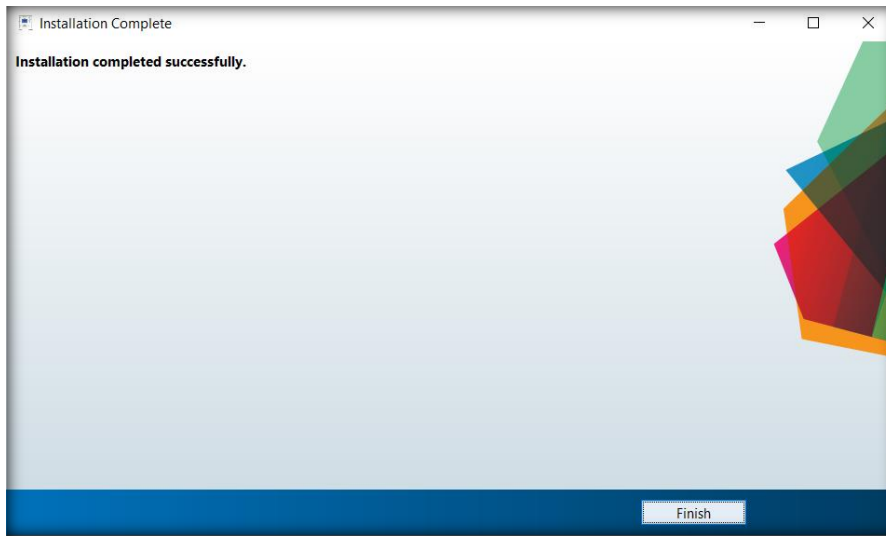
e) In the following window, click on “Yes” button. Then, click on “Next” button:



f) In the following window, click on “Install” button:



g) Once you have completed the previous steps, the installation process will be finished. An example of the final installation screen is shown below:

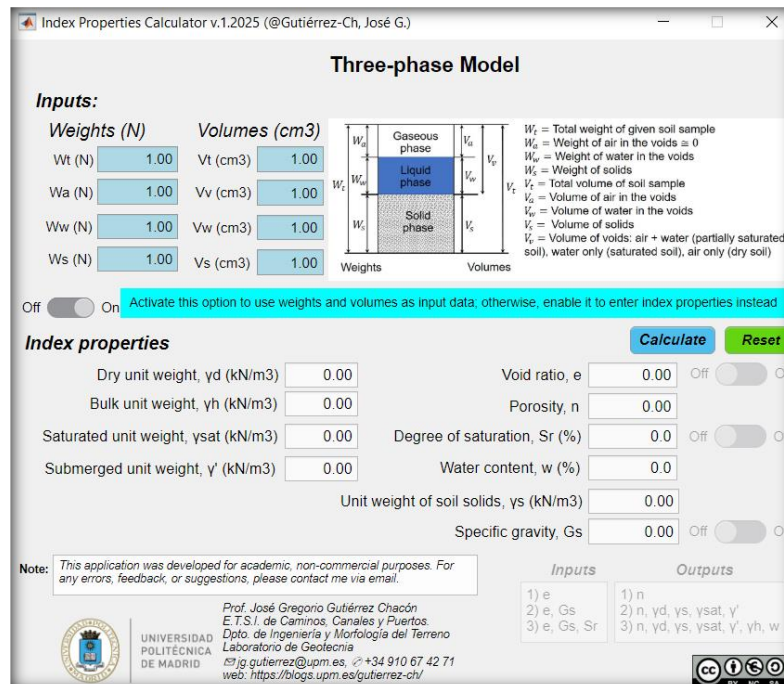


### 1.4 Accessing the App

a) Navigate to the installation directory at:

*C:\Program Files\Index\_Properties\_Calculator\_v25\_1\application*

b) Double-click the file "Elementary\_Properties\_v25\_1.exe". After a few seconds, the main application window will appear:



## 2 Theoretical Background

The application enables the estimation of index soil properties by considering soil as a Three-phase system (see Fig. 1): the solid phase (consisting of mineral and organic matter), the liquid phase (consisting of water or another fluid present in the voids or pores), and the gaseous phase (air or another gas within the pores). Based on this system, various index properties can be described that help characterize a given soil sample.

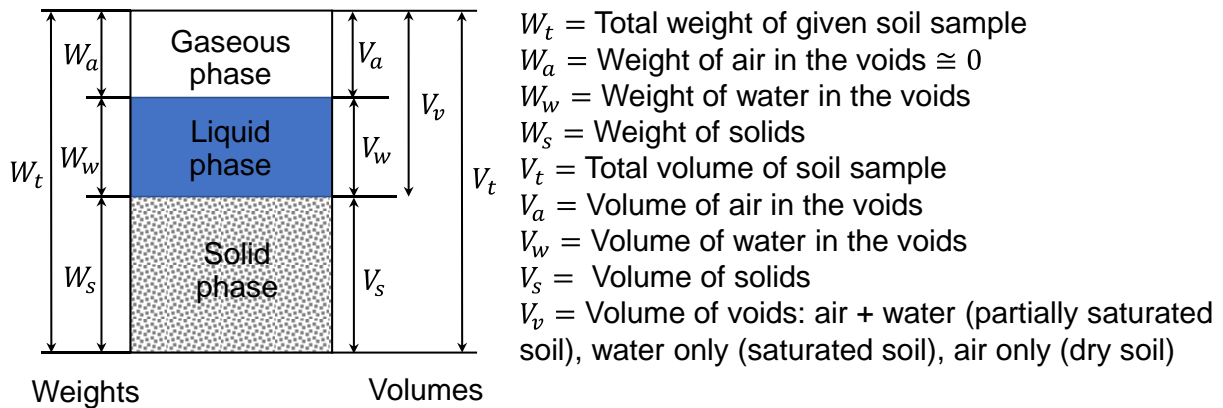


Fig. 1. Conceptual Three-phase Model. Volumes expressed in  $\text{cm}^3$  and Weights in Newtons.

### 2.1 Equations

- Porosity,  $n$ :

$$n = \frac{V_v}{V_t}$$

- Void ratio,  $e$ :

$$e = \frac{V_v}{V_s}$$

- Degree of saturation,  $S_r$  (%):

$$S_r = \frac{V_w}{V_v} \times 100$$

- Dry unit weight,  $\gamma_d$  ( $\text{kN}/\text{m}^3$ ):

$$\gamma_d = \frac{W_s}{V_t}$$

- Bulk or moist unit weight,  $\gamma_h$  ( $\text{kN}/\text{m}^3$ ):

$$\gamma_h = \frac{W_s + W_w + W_a}{V_t}$$

- Saturated unit weight,  $\gamma_{sat}$  ( $\text{kN}/\text{m}^3$ ):

$$\gamma_h = \frac{W_s + W_w}{V_t}$$



- Submerged unit weight,  $\gamma'$  ( $kN/m^3$ ):

$$\gamma_h = \frac{W_s - \gamma_w \cdot V_s}{V_t}$$

- Unit weight of soil solids,  $\gamma_s$  ( $kN/m^3$ ):

$$\gamma_s = \frac{W_s}{V_s}$$

- Specific gravity,  $G_s$ :

$$G_s = \frac{\gamma_s}{\gamma_w}$$

- Water content,  $w$  (%):

$$w = \frac{W_w}{W_s} \times 100$$

- Relationships between  $e$ ,  $G_s$  and other index properties:

$$n = \frac{e}{1 + e}$$

$$\gamma_d = \frac{\gamma_s}{1 + e}$$

$$\gamma_s = \gamma_w \cdot G_s$$

$$\gamma_{sat} = \gamma_d + n \cdot \gamma_w$$

$$\gamma_{sum} = \gamma_{sat} - \gamma_w$$

- Relationships between  $e$ ,  $G_s$ ,  $S_r$  and other index properties:

Same as above

$$\gamma_h = \frac{\gamma_s + S_r \cdot e \cdot \gamma_w}{(1 + e)}$$

$$w = S_r \frac{e \cdot \gamma_w}{\gamma_s}$$

Note: Weight of water is considered as  $\gamma_w = 10 \text{ kN/m}^3$



### 3 General Navigation of the App

The Soil Index Properties application features a user-friendly graphical interface and offers two calculation modes:

#### a) Mode 1:

This mode allows the calculation of soil index properties using input data related to the weights and volumes of a soil sample based on the three-phase system. To activate this mode, the toggle switch must be set to the “On” position, as shown in Fig. 2.

Please note that in this mode, only weights and volumes can be entered; other types of variables are not available for input.

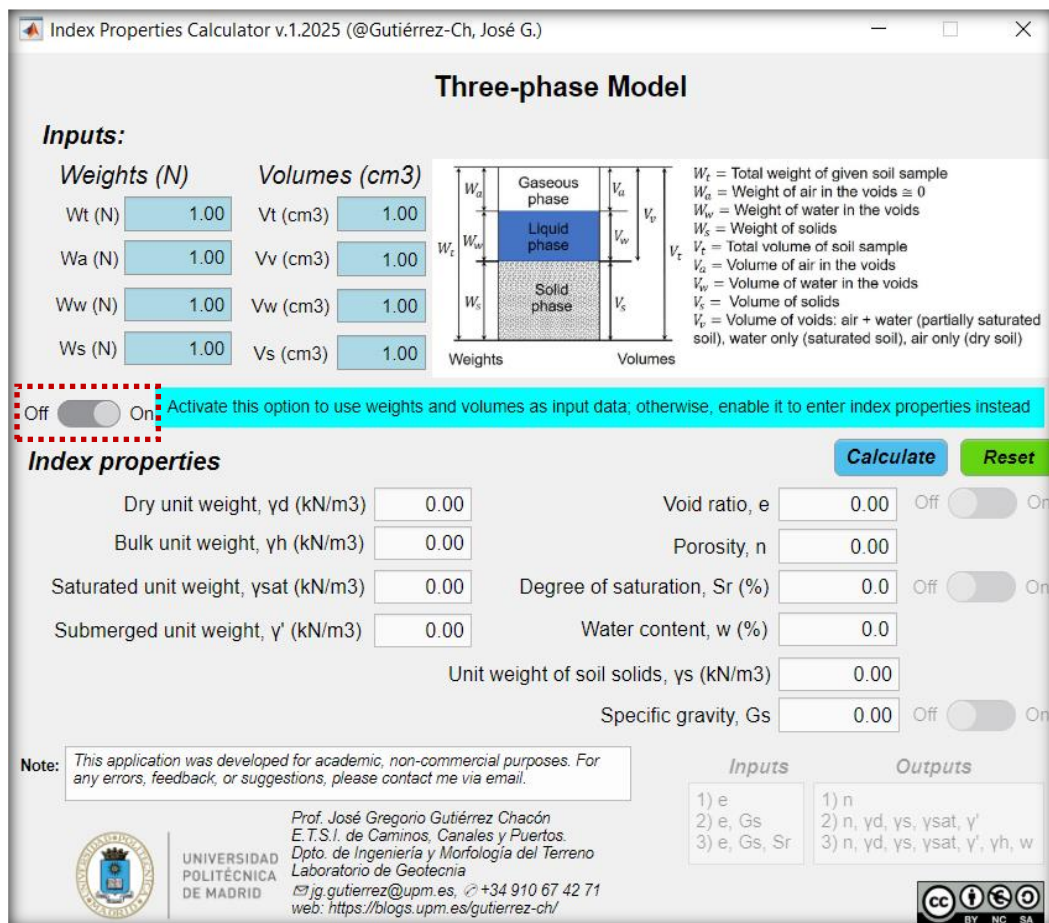


Fig. 2. Calculation Interface – Mode 1.

#### b) Mode 2:

This mode enables the calculation of soil index properties using other previously known parameters, such as the void ratio ( $e$ ), the specific gravity ( $G_s$ ), and the degree of saturation ( $S_r$ ). To activate this mode, the main switch (see Fig. 3) must be set to the “Off”

position. Then, each individual switch corresponding to the properties to be entered must be turned “On”.

Please note that in this mode, the input of sample weights and volumes is disabled and calculations are based only on other soil index properties.

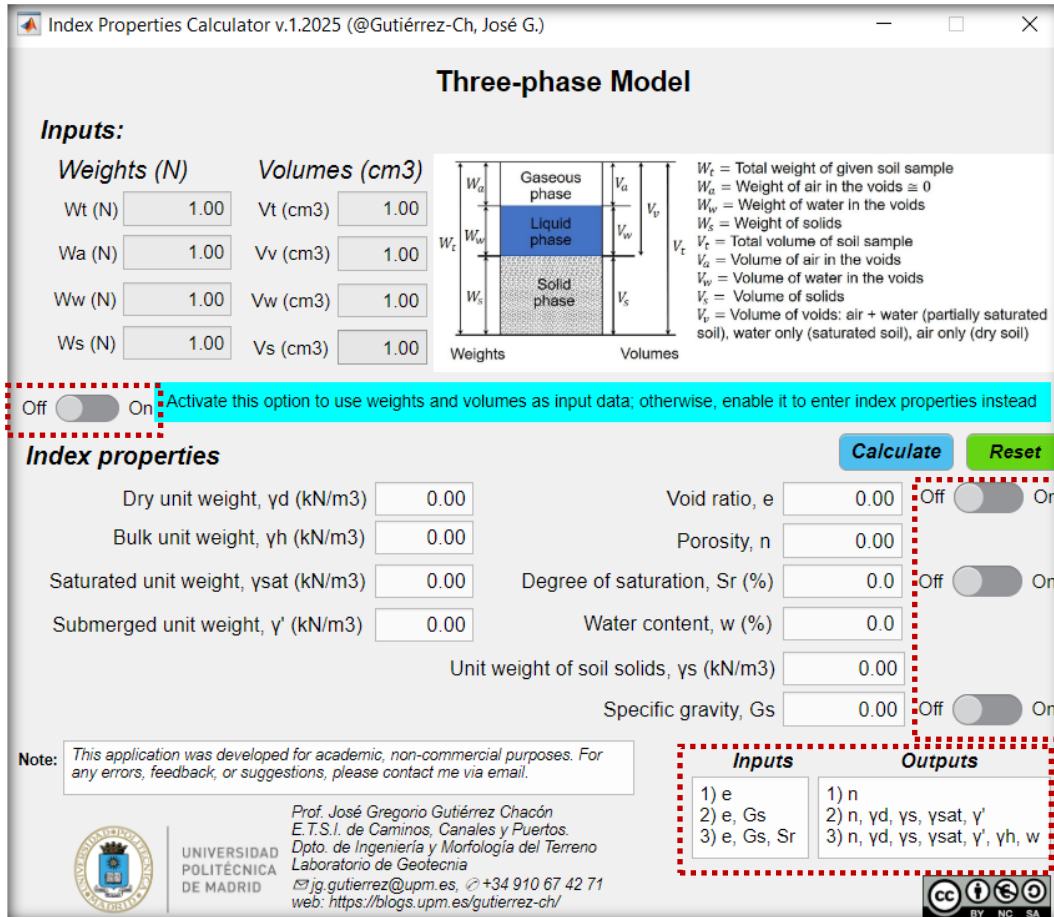


Fig. 3. Calculation Interface – Mode 2.

Additionally, as shown in Fig. 3, the properties calculated in Mode 2 depend directly on the input data provided. Specifically:

- If only the void ratio ( $e$ ) is entered, the application will calculate the porosity ( $n$ ).
- If both the void ratio ( $e$ ) and the specific gravity ( $G_s$ ) are entered, the following properties are obtained: porosity ( $n$ ), unit weight of soil solids ( $\gamma_s$ ), dry unit weight ( $\gamma_d$ ), saturated unit weight ( $\gamma_{sat}$ ), and submerged unit weight ( $\gamma'$ ).
- Finally, if the void ratio ( $e$ ), the specific gravity ( $G_s$ ), and the degree of saturation ( $S_r$ ) are all provided, the application calculates: porosity ( $n$ ), unit weight of soil



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solids ( $\gamma_s$ ), dry ( $\gamma_d$ ), saturated ( $\gamma_{sat}$ ), submerged ( $\gamma'$ ), and bulk unit weight ( $\gamma_h$ ), as well as the water content ( $w$ ) of the sample.

Once the appropriate input data have been entered according to the selected calculation mode (**Mode 1** or **Mode 2**), click on the "**Calculate**" button (blue box shown in Fig. 2 or Fig. 3) to compute the soil's index properties.

To begin a new calculation, press the "**Reset**" button (green box shown in Fig. 2 or Fig. 3).



## 4 Examples

### Exercise 1 (Mode 1 illustration):

A partially saturated soil sample has the following known parameters: Total volume ( $V_t$ ) =  $50 \text{ cm}^3$ , Total weight ( $W_t$ ) =  $0.95 \text{ N}$ , Weight of solids ( $W_s$ ) =  $0.75 \text{ N}$ , Specific gravity ( $G_s$ ) =  $2.68$

### Tasks:

Using the above data, calculate the following index properties:

- Water content, void ratio, porosity and degree of saturation.
- Unit weights: dry ( $\gamma_d$ ), bulk ( $\gamma_h$ ), saturated ( $\gamma_{sat}$ ), and submerged ( $\gamma'$ )

### Solution:

To solve this exercise, the calculation mode switch must be set to "On", and the corresponding sample weights and volumes must be entered as input data. When this mode is activated, all fields related to weights and volumes are highlighted in light blue, indicating that they have been selected as inputs (see Fig. 4).

It is important to note that the application does not automatically compute missing input values; these must be calculated manually by the student using the equations provided in class. However, for verification and comparison purposes, the correct values are displayed in Fig. 4.

Fig. 4. Application Example: Mode 1 Calculation.

Once the input data have been provided, pressing the “**Calculate**” button will generate the soil index properties required for the exercise (see Fig. 5).

**Index Properties Calculator v.1.2025 (@Gutiérrez-Ch, José G.)**

### Three-phase Model

**Inputs:**

Weights (N)	Volumes (cm3)
Wt (N) 0.95	Vt (cm3) 50.00
Wa (N) 0.00	Vv (cm3) 22.00
Ww (N) 0.20	Vw (cm3) 20.00
Ws (N) 0.75	Vs (cm3) 28.00

**Diagram:** A vertical bar representing a soil sample, divided into three phases: Gaseous phase (top), Liquid phase (middle), and Solid phase (bottom). Weights (W<sub>t</sub>, W<sub>a</sub>, W<sub>w</sub>, W<sub>s</sub>) and Volumes (V<sub>t</sub>, V<sub>v</sub>, V<sub>w</sub>, V<sub>s</sub>) are indicated on the left and right sides respectively.

**Legend:**

- W<sub>t</sub> = Total weight of given soil sample
- W<sub>a</sub> = Weight of air in the voids ≅ 0
- W<sub>w</sub> = Weight of water in the voids
- W<sub>s</sub> = Weight of solids
- V<sub>t</sub> = Total volume of soil sample
- V<sub>v</sub> = Volume of air in the voids
- V<sub>w</sub> = Volume of water in the voids
- V<sub>s</sub> = Volume of solids
- V<sub>v</sub> = Volume of voids: air + water (partially saturated soil), water only (saturated soil), air only (dry soil)

Off  On  Activate this option to use weights and volumes as input data. otherwise, enable it to enter index properties instead

**Index properties** **Calculate** **Reset**

Dry unit weight, γ <sub>d</sub> (kN/m <sup>3</sup> )	15.00	Void ratio, e	0.79	Off <input type="checkbox"/> On <input type="checkbox"/>
Bulk unit weight, γ <sub>h</sub> (kN/m <sup>3</sup> )	19.00	Porosity, n	0.44	
Saturated unit weight, γ <sub>sat</sub> (kN/m <sup>3</sup> )	19.40	Degree of saturation, S <sub>r</sub> (%)	90.9	Off <input type="checkbox"/> On <input type="checkbox"/>
Submerged unit weight, γ' (kN/m <sup>3</sup> )	9.40	Water content, w (%)	26.7	
		Unit weight of soil solids, γ <sub>s</sub> (kN/m <sup>3</sup> )	26.79	
		Specific gravity, G <sub>s</sub>	2.68	Off <input type="checkbox"/> On <input type="checkbox"/>

**Note:** This application was developed for academic, non-commercial purposes. For any errors, feedback, or suggestions, please contact me via email.

**Inputs** **Outputs**

1) e	1) n
2) e, G <sub>s</sub>	2) n, γ <sub>d</sub> , γ <sub>s</sub> , γ <sub>sat</sub> , γ'
3) e, G <sub>s</sub> , S <sub>r</sub>	3) n, γ <sub>d</sub> , γ <sub>s</sub> , γ <sub>sat</sub> , γ', γ <sub>h</sub> , w

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Fig. 5. Demonstration results – Mode 1 Calculation.

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## Exercise 2 (Mode 2 illustration):

A soil sample has the following properties: void ratio  $e = 0.33$  and specific gravity  $G_s = 2.6$ . Tasks:

Using the above data, calculate the following index properties:

- Water content, void ratio, porosity, and degree of saturation.
- Dry unit weight ( $\gamma_d$ ),
- Bulk unit weight ( $\gamma_h$ ) considering a degree of saturation  $S_r = 65\%$ ,
- Unit weights: saturated ( $\gamma_{sat}$ ), and submerged ( $\gamma'$ ).

### Solution:

In this case, Calculation **Mode 2** of the application is used, which requires the main switch to be set to the "Off" position. Additionally, the individual switches corresponding to the selected input parameters must be turned "On". For this example, the input parameters are the void ratio ( $e$ ), the specific gravity of solids ( $G_s$ ), and the degree of saturation ( $S_r$ ).

When these individual switches are activated, their corresponding input fields are highlighted in light blue, indicating that they have been selected for data entry (see Fig. 6).

Fig. 6. Application Example: Mode 2 Calculation.

Once the input data have been provided, pressing the “**Calculate**” button will generate the elemental properties of the soil sample required for the exercise (see Fig. 7).

Fig. 7. Demonstration Results – Mode 2 Calculation

## 5 Technical Support and Contact

If you encounter any errors or have suggestions for improvement, please contact me at: [jg.gutierrez@upm.es](mailto:jg.gutierrez@upm.es)