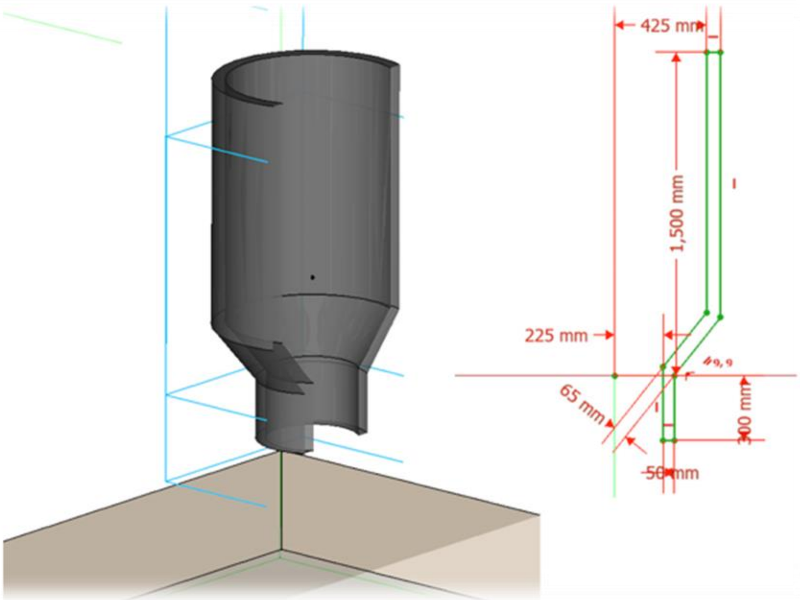
Particle-based continuum solutions for extreme geoengineering, geomechanics & geophysics applications



GeoXPM

Tutorial Manual

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Introduction

GeoXPM is a new generation of computational software package that was originally developed by Prof Ha H. Bui and his research team at Monash University in Australia based on the Smoothed Particle Hydrodynamics (SPH) method. It has been developed specifically to address the ever-evolving demands of solving intricate geotechnical engineering, geomechanics and geophysics challenges, particularly those involving fracturing, large deformation and flow behaviours of geomaterials. One standout feature of GeoXPM is its interactive graphical user-interface, which empowers users to effortlessly generate and modify complex computational models without encountering any obstacles. The calculation procedure within GeoXPM is both robust and fully automated, eliminating the need for extensive training or specialised knowledge. With GeoXPM, academics and professionals alike can unlock the full potential of engineering applications, pushing boundaries and delivering remarkable results that exceed expectations.

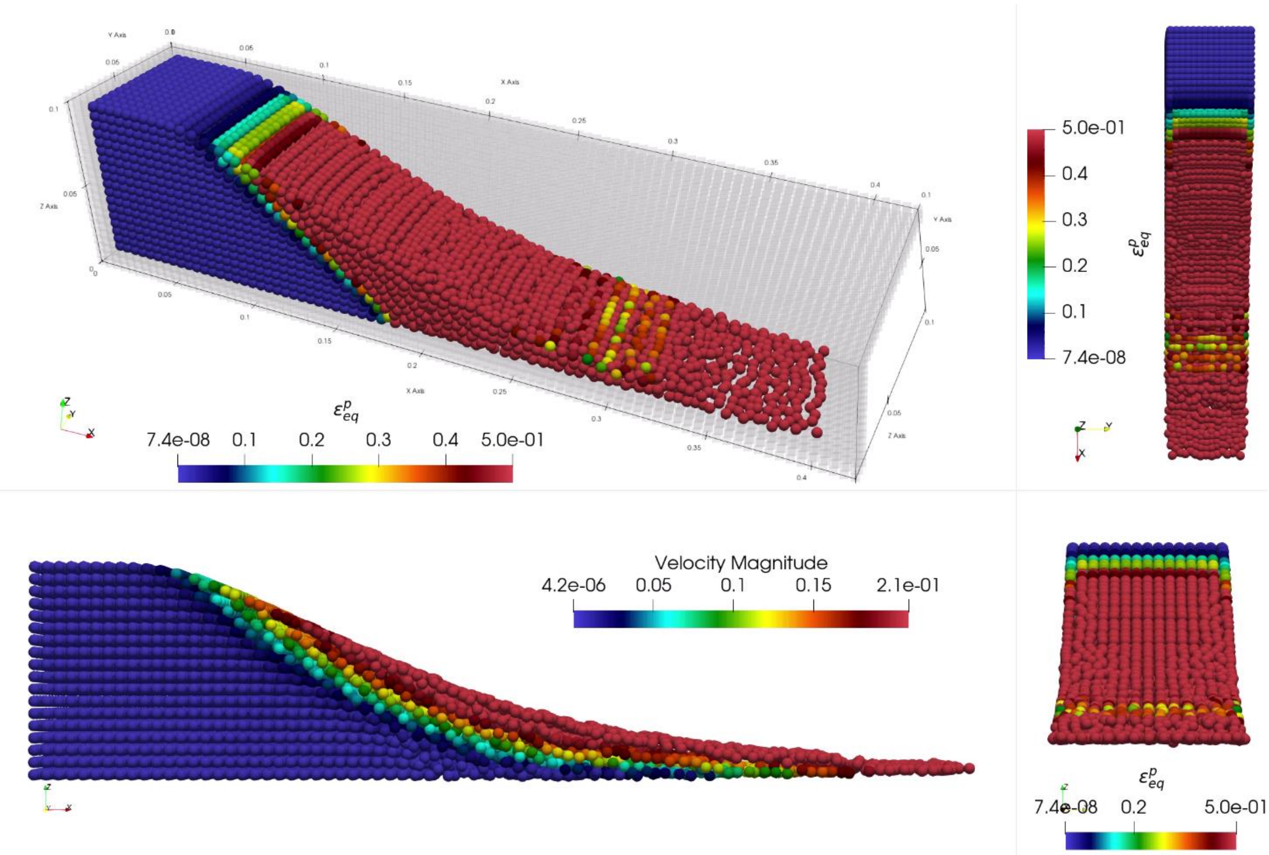
The tutorial explores a wide range of challenging and practical scenarios that encompass the intricate aspects of large deformation and post-failure behaviour in geomaterials. The main aim is to equip new users with a comprehensive understanding of GeoXPM. However, it is crucial to recognise that this tutorial should not be solely relied upon as the basis for practical projects. Instead, it serves as an invaluable resource to familiarise users with the functionalities and capabilities of the software.

Users are expected to possess a fundamental understanding of the SPH method and constitutive modelling of geomaterials. For those who are new to the software, it is highly recommended that they adhere to the default setting parameters and follow the step-by-step procedure meticulously to ensure accurate results. It is important to note that variations in hardware and software configurations may yield slight differences in the obtained results.

This Tutorial Manual does not provide the theoretical background information on the SPH method or elaborate on the specific details of the constitutive models utilised within the software. Therefore, users are highly advised to refer to the provided references for comprehensive information regarding the SPH method and constitutive models implemented in GeoXPM. These references offer in-depth insights into the underlying principles and methodologies employed, allowing users to gain a thorough understanding of the theoretical aspects involved.

Example:

3D Granular Flow



In this project, we will model a simple granular flow. You will learn about using:

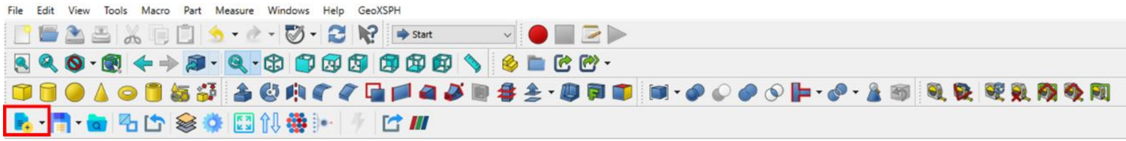
- **Basic drawing with primitive objects**
- **Basic functions of GeoXSPH, including Meshing, Staging, Material models and Visualisation**

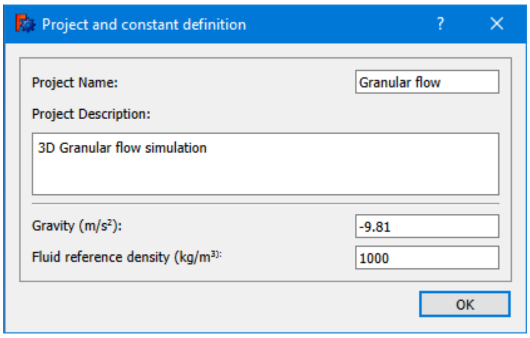
We will follow the below standard workflow:

1. Create a new project.
2. Create initial geometry.
3. Input SPH parameters.
4. Create material models.
5. Include objects in simulations and assign material properties.
6. Define construction stages.
7. Define meshing sequences.
8. Mesh objects – generate particles for calculations.
9. Calculate.
10. Post-processing - Visualisation: extract, data mining.

➢ Step 1. Create a new project

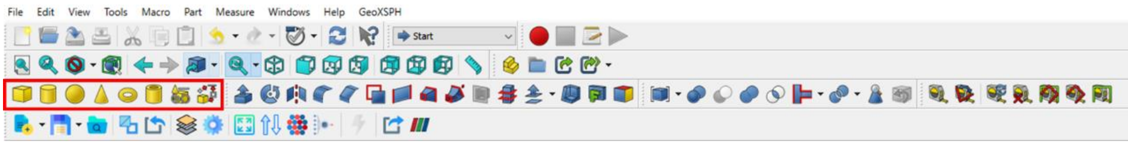
a. Click the “New Tool” button to create a new project as the given dialogue below.
b. Enter the project name and project description.

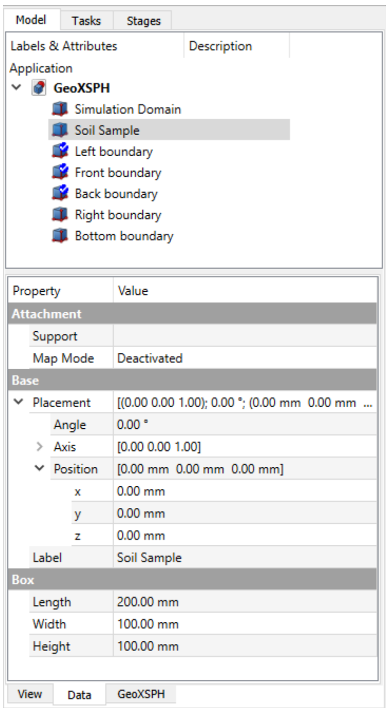




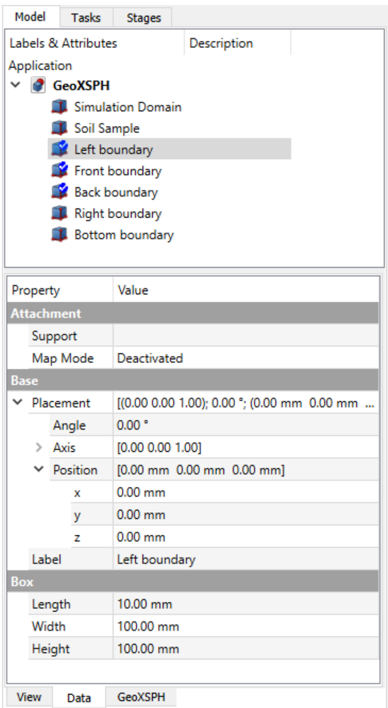
➢ Step 2. Create initial geometry

a. Using the “Primitives” toolbox (Cube tool  in this case) to draw the geometries of soil (named “Soil Sample” object) and Boundaries (named “Bottom boundary”, “Front boundary”, “Back boundary”, “Left boundary” and “Right boundary” objects).
b. Define the dimensions and positions of each object.

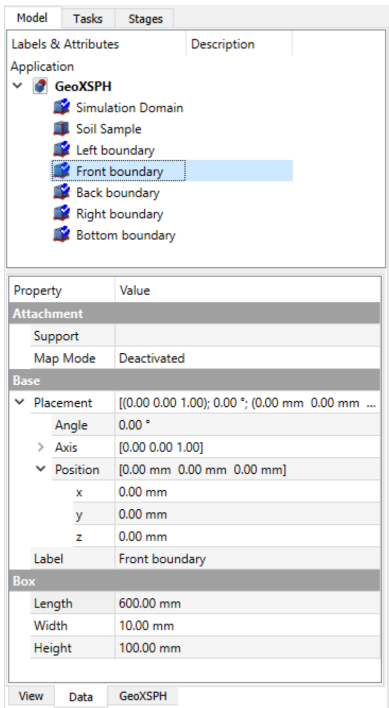




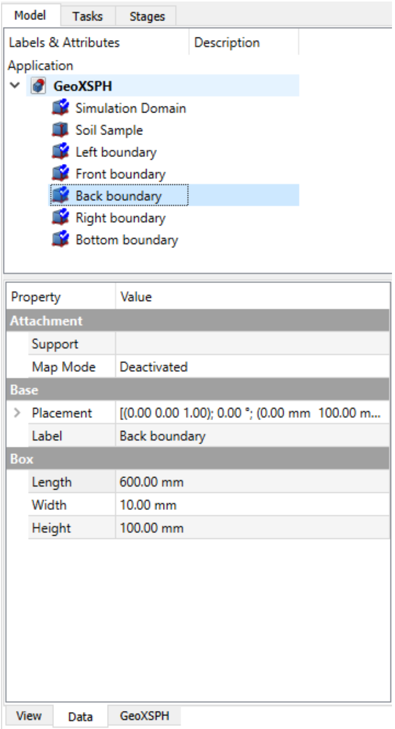
Soil domain



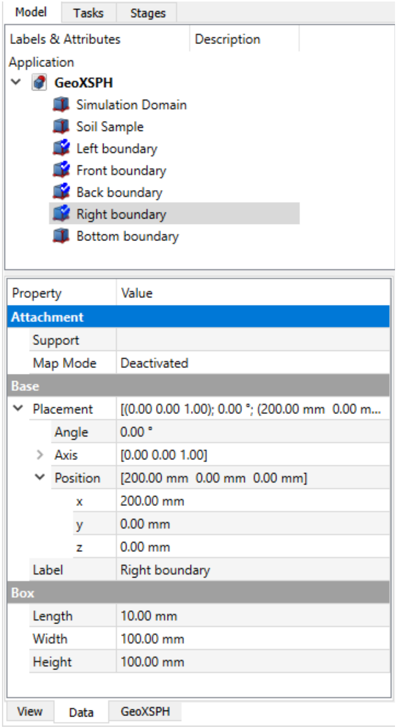
Left boundary



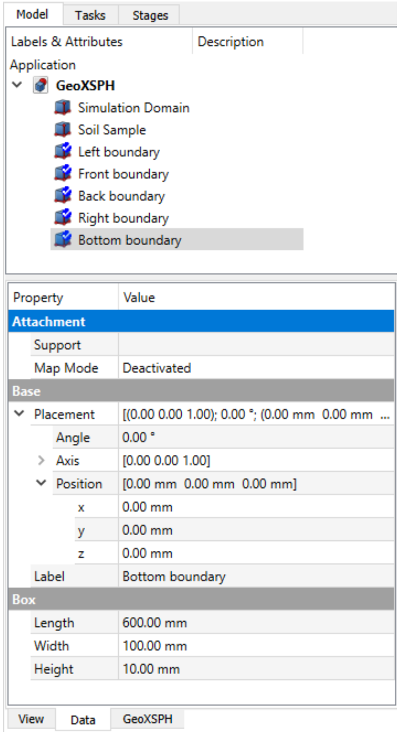
Front boundary



Back boundary



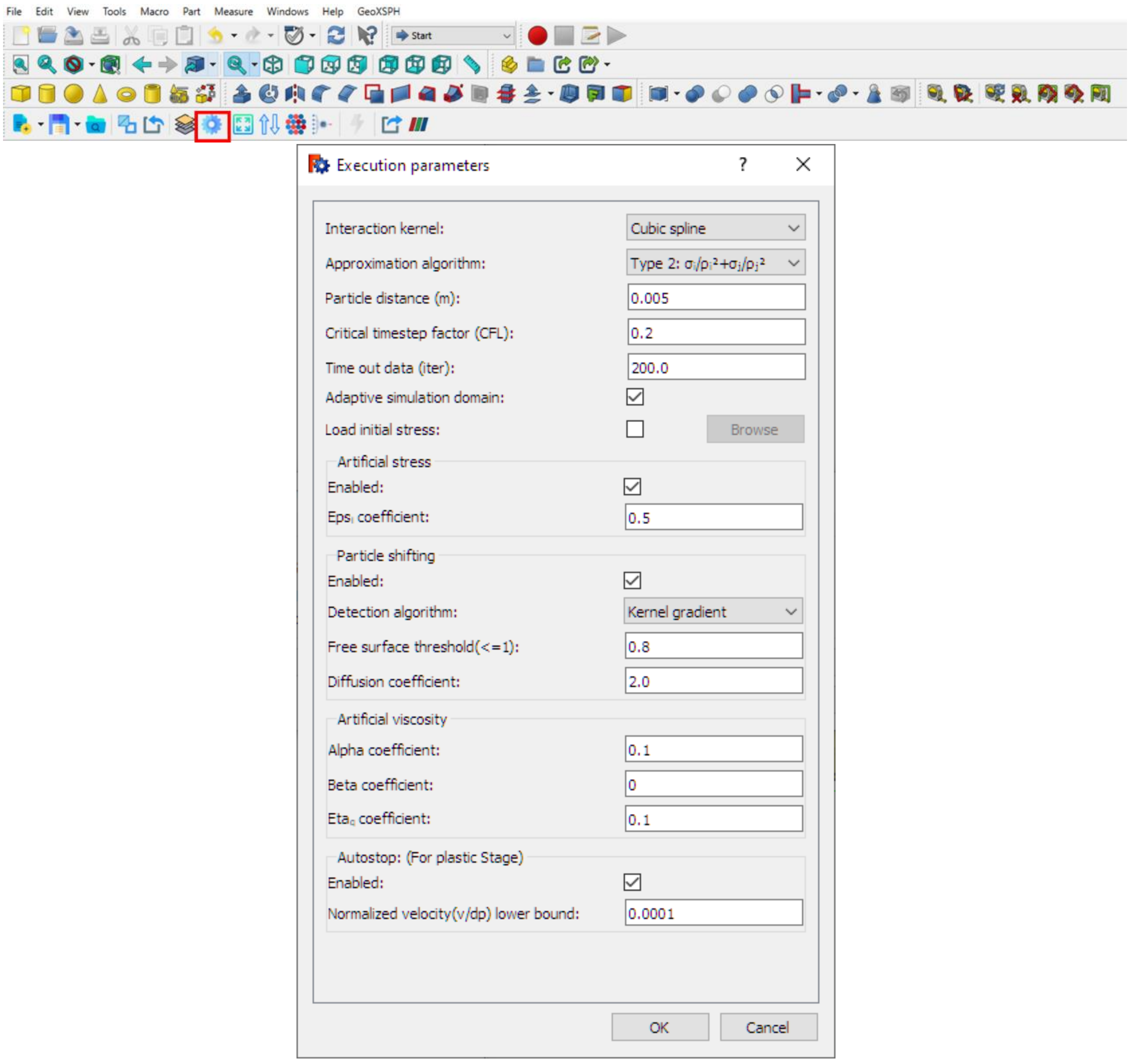
Right boundary



Bottom boundary

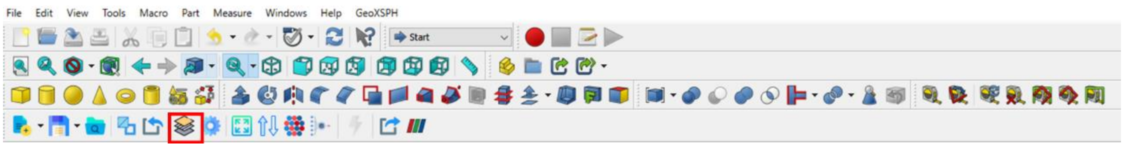
➢ Step 3. Input SPH parameters

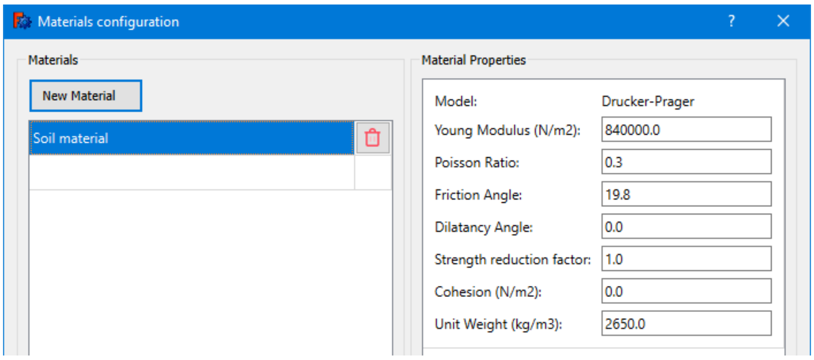
a. Enter the SPH parameters into the dialogue.



➢ Step 4. Input material properties

a. Click the Material property button, select the used constitutive model (i.e., Elastic-perfectly plasticity (DP) model) provided in the “new material” button, and enter the material parameters.

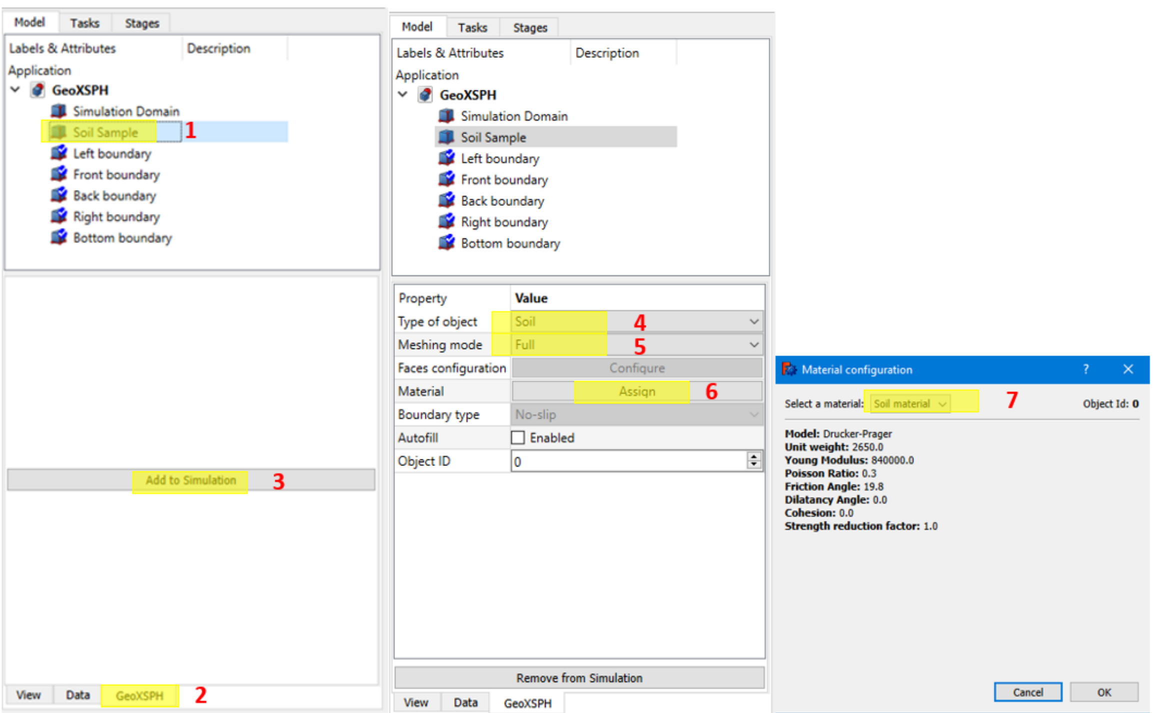




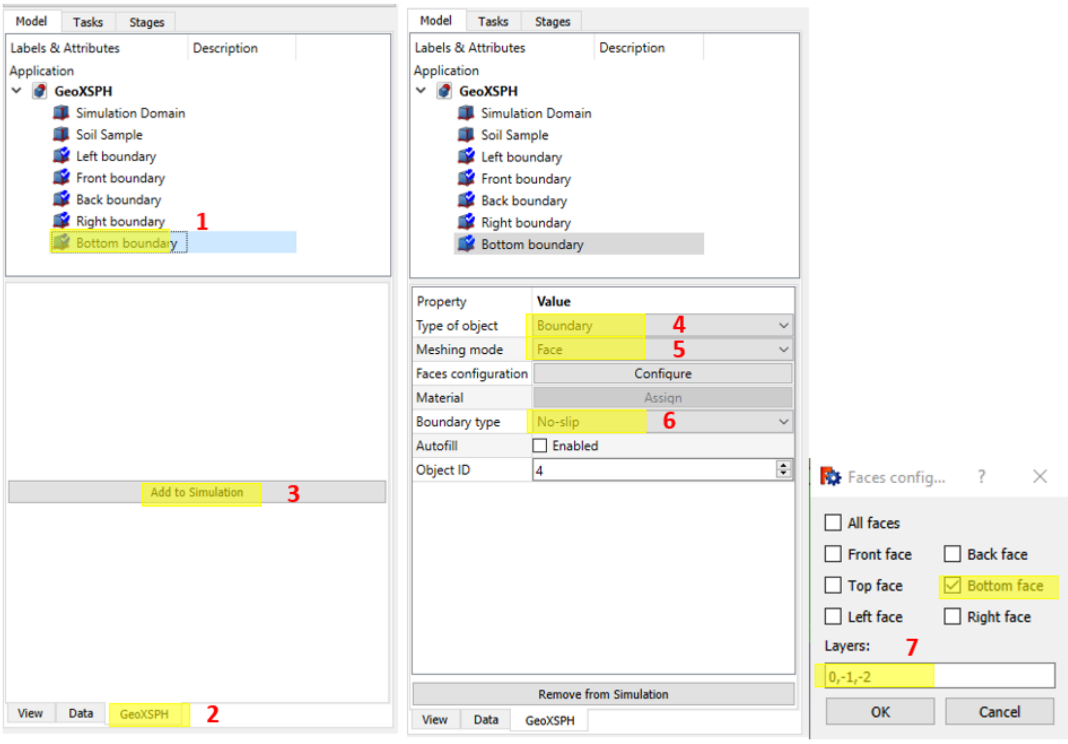
Hint: The timestep for the elastoplastic model depends heavily on the sound speed, which depends on the material's Young Modulus and Unit Weight. Decreasing Young Modulus and increasing Unit Weight will increase the timestep, making the simulation faster but risking extreme particle overlapping and penetration.

➢ Step 5. Include objects in simulations and assign material properties

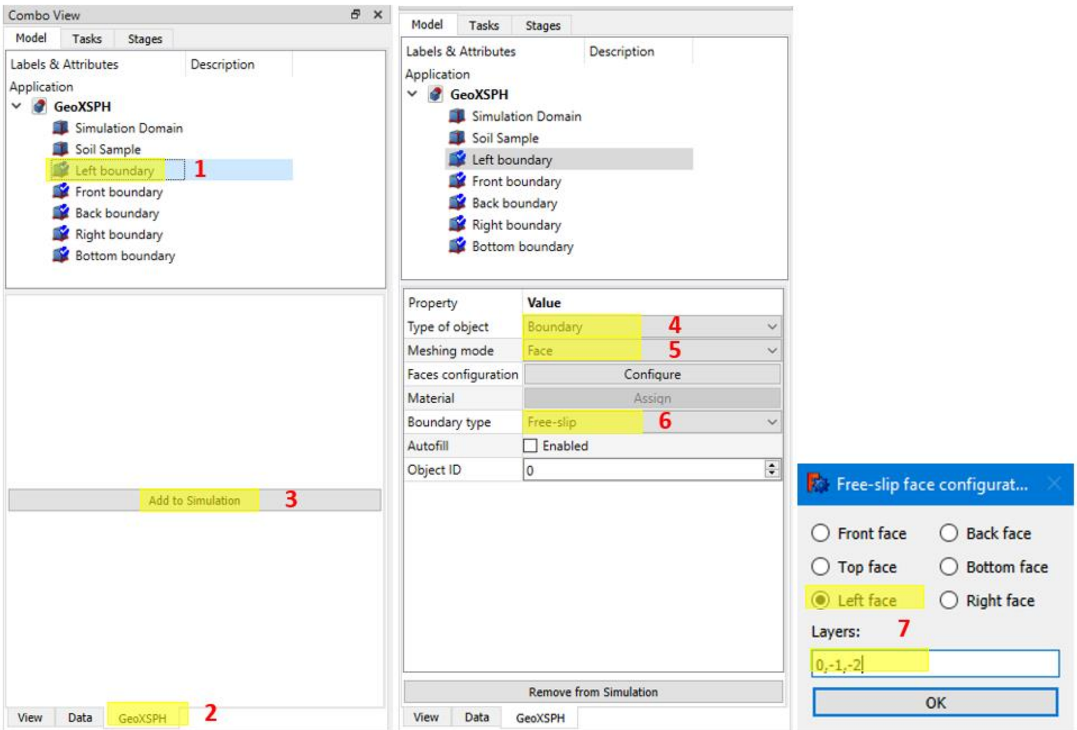
a. Soil object: Select the “Soil sample” in the “Model” tab and click “Add to Simulation” under the “GeoXSPH” tab. And then, select the “Type of object” as “Soil” and the meshing mode as “Full”. In the next step, click the “Assign” button to assign the “Soil material” to the soil in the dialogue of the material configuration.



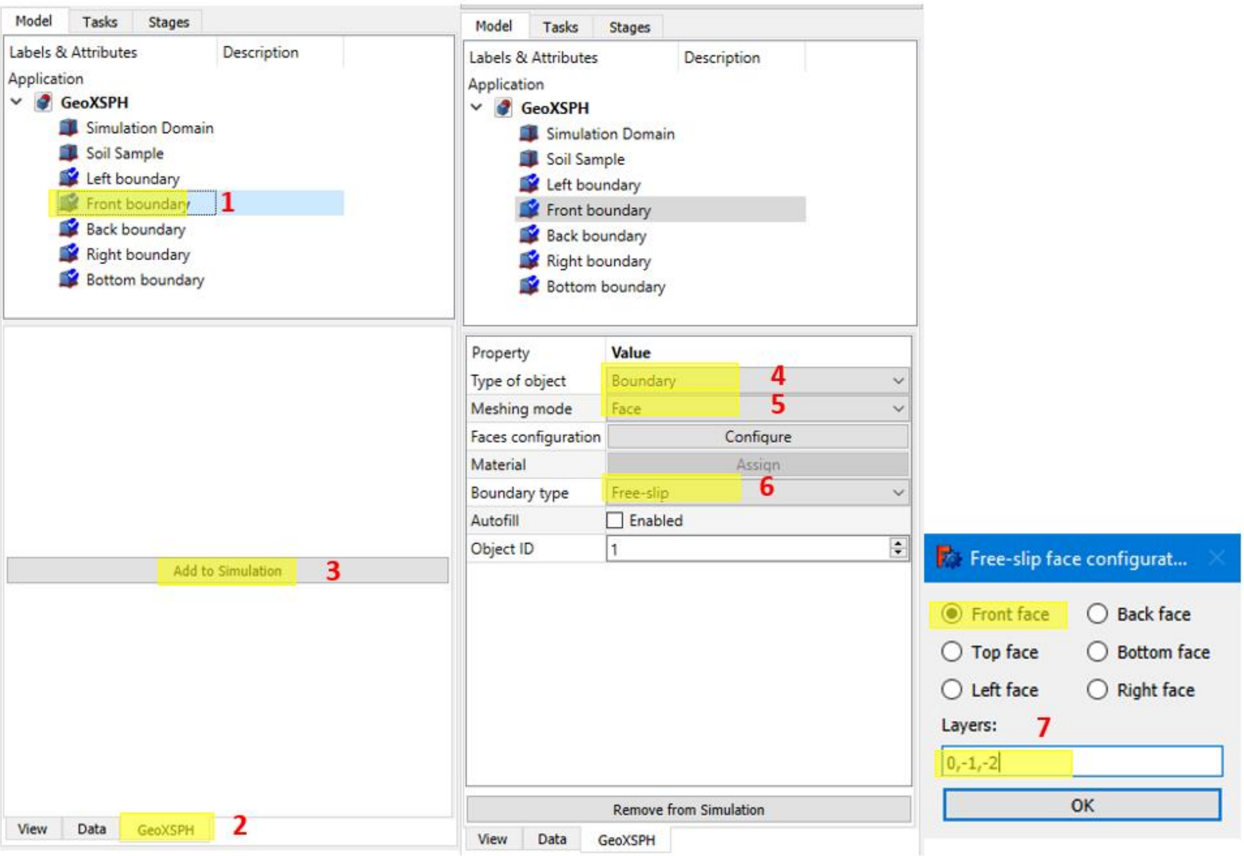
b. “Bottom boundary” object: Select the “Bottom boundary” in the “Model” tab and click “add to Simulation” under the “GeoXSPH” tab. And then select the “Type of object” as “Boundary”, meshing mode as “Face”, and the “Boundary type” as “No-slip”. In the next step, click the “Configure” button to define the boundary surface in the dialogue of the face configuration.

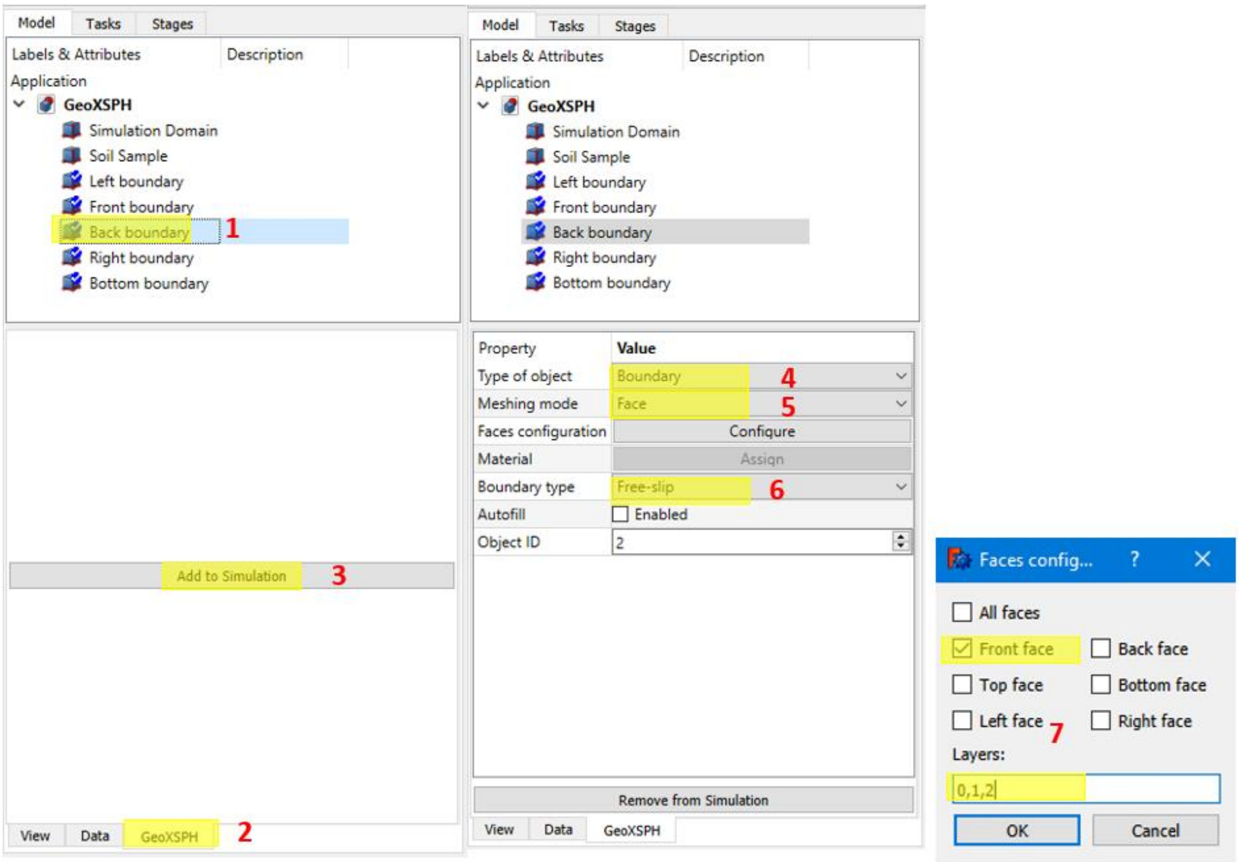


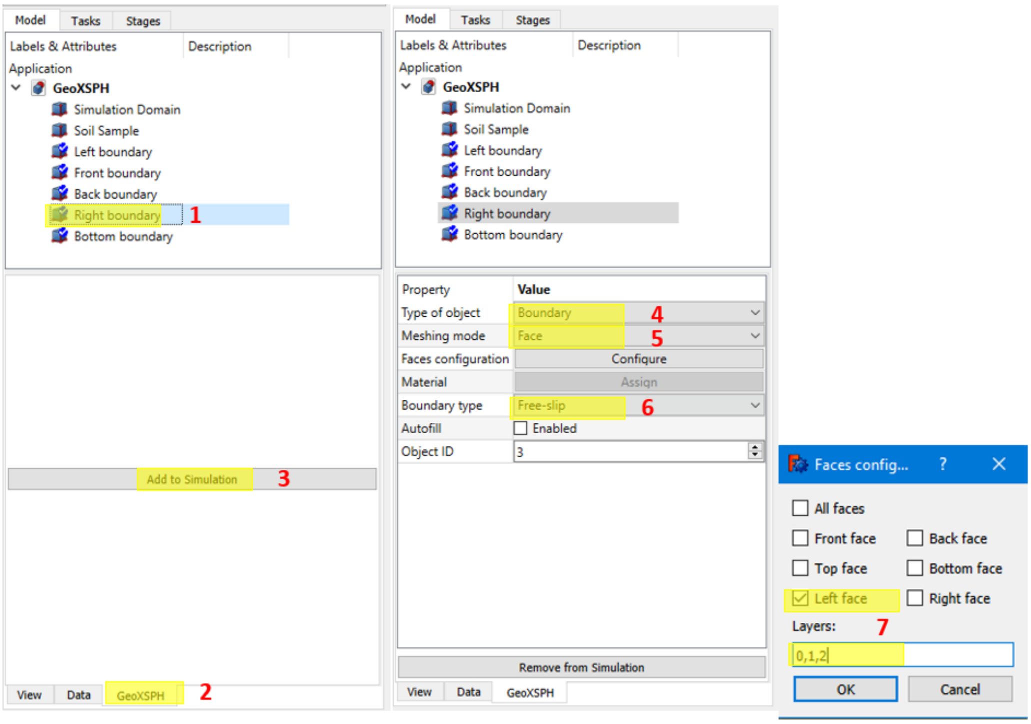
c. “Left boundary” object. Select the “Left boundary” in the “Model” tab and click “Add to Simulation” under the “GeoXSPH” tab. And then select the “Type of object” as “Boundary”, meshing mode as “Face”, and the “Boundary type” as “Free-slip”. In the next step, define the boundary surface in the dialogue of the face configuration.



d. Repeat step c for the rest of the free-slip boundary objects, including: “Front boundary”, “Back boundary” and “Right boundary”.







➢ Step 6. Define construction stages

a. Go to the Stage tab and click "Add stage".

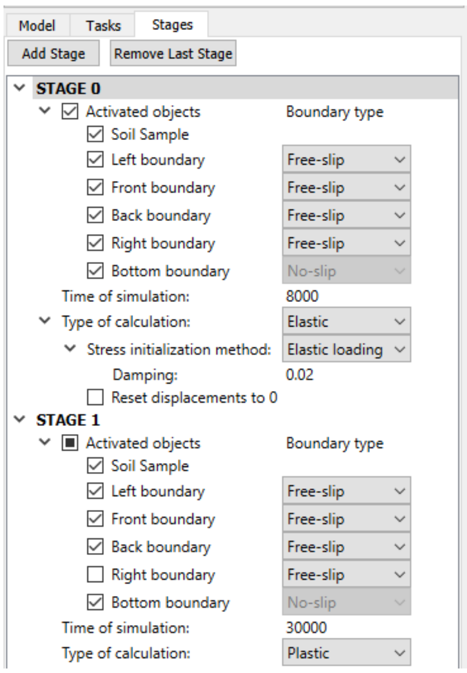
b. Click the checkbox "Activated objects" to activate all objects in the simulation.

c. Set Stage 0 for the stress initialisation using the elastic loading method. Set the "Type of calculation" to "Elastic", "Stress initialisation method" to "Elastic loading" and the "Time of simulation" to 8000.

d. Tick the checkbox next to "Reset displacement to 0" to reset displacement after stress initialisation.

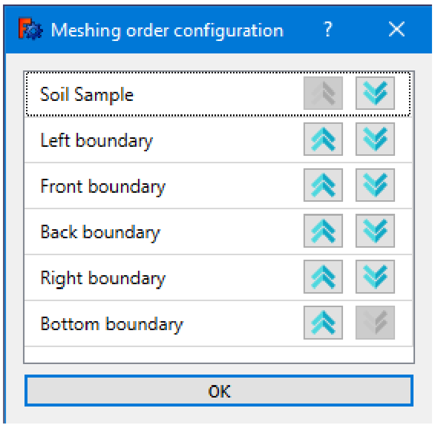
e. Add Stage 1 for the elastoplastic analysis. Click the checkbox "Activated objects" to activate all objects in the simulation, then untick "Right boundary" to deactivate (remove) the right wall in this stage.

f. Set Stage 1's "Type of calculation" to "Plastic" and the "Time of simulation" to 30000.



➢ Step 7. Define the meshing sequence

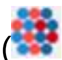
Click the meshing order button, and change the meshing sequence for the included objects in step 5. Note that the lower object will overwrite the upper one if there are overlaps.

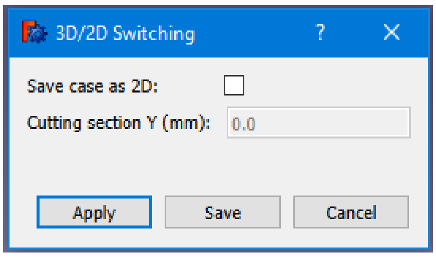


Meshing order configuration

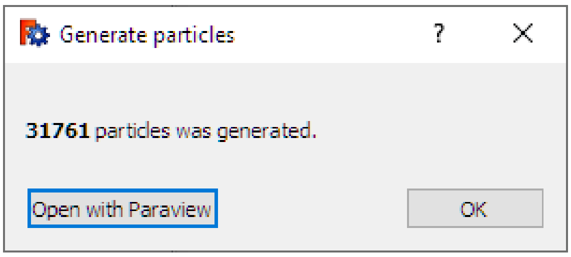
➢ Step 8. Generate particles for computations

a. Before meshing, click the "Save" button () to save the project as 2D or 3D based on your need.
b. Click the "Autofit simulation domain" button ()to fit all simulated objects in the Simulation domain.

a. Click the "Generate particles" button() to mesh the computational domain.
b. After meshing, click "Open with Paraview" to view the particle configuration.



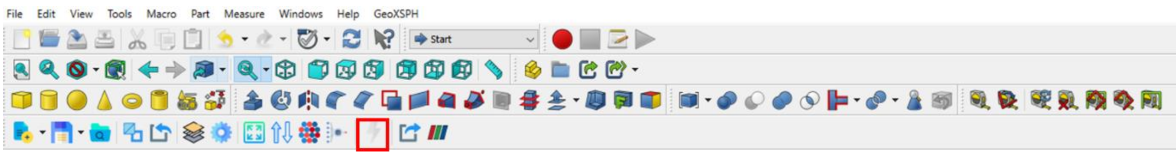
Save the project as 3D

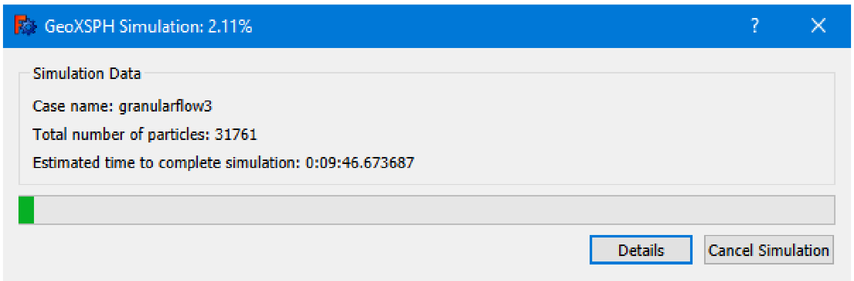


Check the particle configuration

➢ Step 9. Start the Calculation

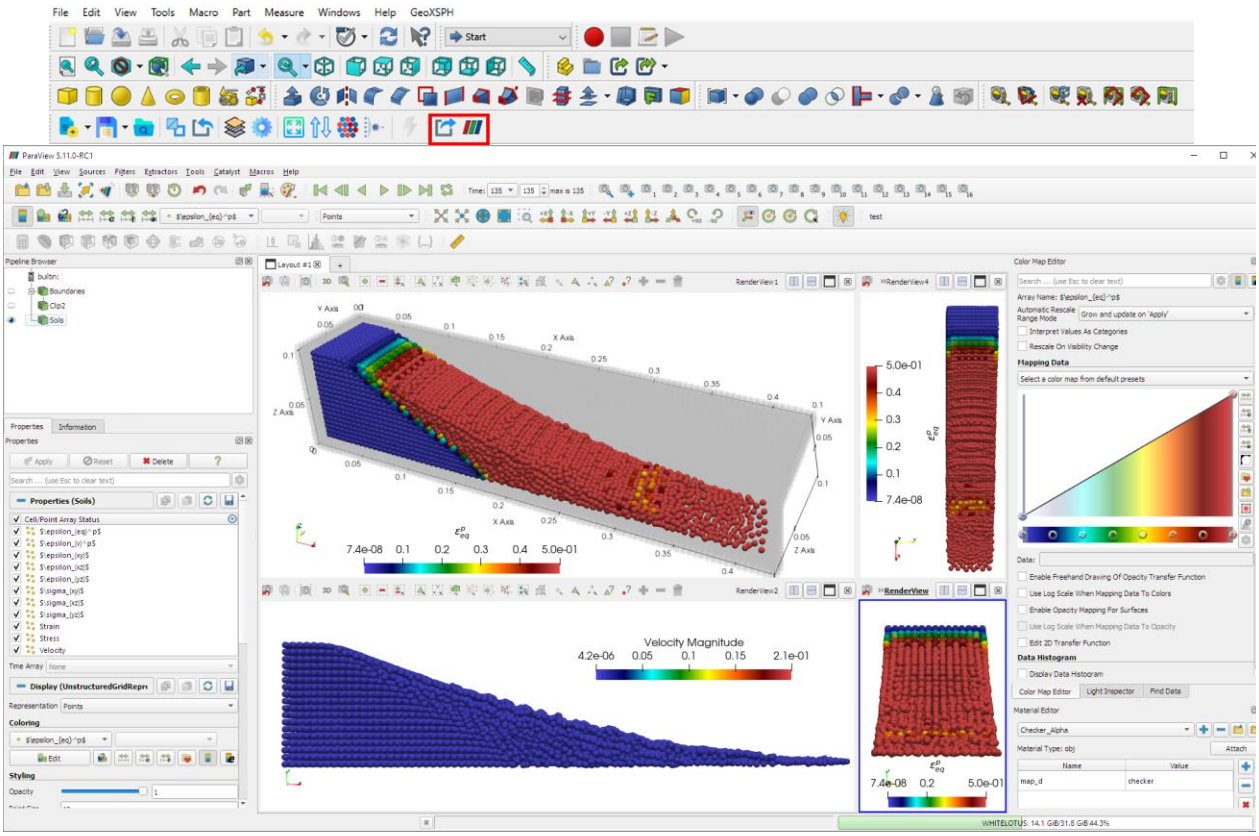
Click the "Run" button and start the calculations.





➢ Step 10. Visualisation

a. Click on the tool "Export output data to VTU format" to start exporting data to Paraview anytime during the simulation or after completion.
b. When the export is done, Paraview will open with already imported results. All the data can be customised and visualised from here.



References:

1. Bui H.H, Nguyen V.T & Nguyen G.D (2023). GeoXPM: Particle-based continuum solutions for extreme geoengineering, geomechanics & geophysics applications, Tutorial Manual. Link
2. Bui H.H, Nguyen G.D (2021). Smoothed particle hydrodynamics (SPH) and its applications in geomechanics: From solid fracture to granular behaviour and multiphase flows in porous media, *Computers and Geotechnics* 138, 104315. Link
3. Bui H.H, Fukagawa R, Sako K & Ohno S (2008). Lagrangian mesh-free particles method (SPH) for large deformation and failure flows of geomaterial using elastic-plastic soil constitutive model, International Journal for Numerical and Analytical Methods in Geomechanics, Vol.32(12), pp.1537-1570. Link