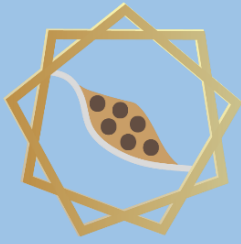
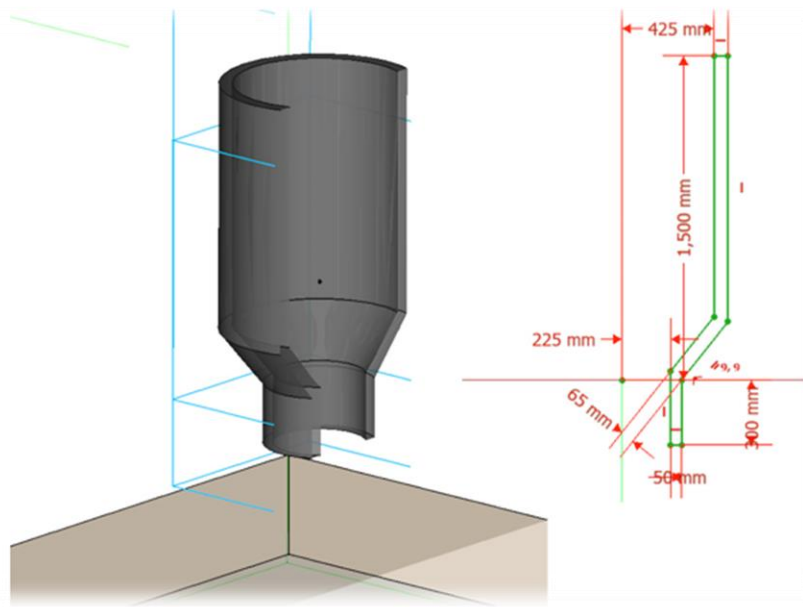


GeoXPM



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



GeoXPM Tutorial Manual

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Tien V. Nguyen
Giang D. Nguyen

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 Hourglass



In this project, you will learn about using:

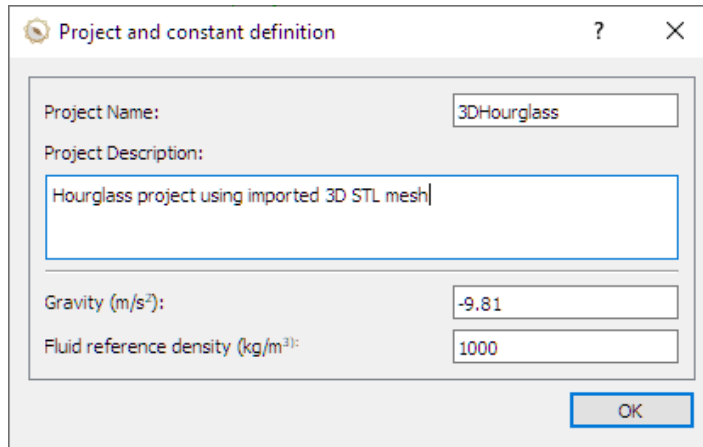
- **External Mesh objects**
- “**FillBox**” tool
- Creating a basic **rendering** with path tracing.

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.

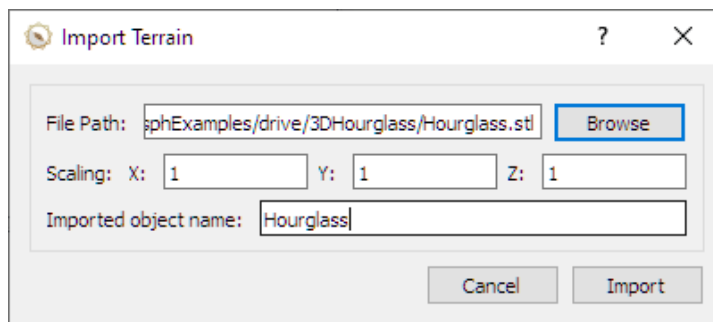
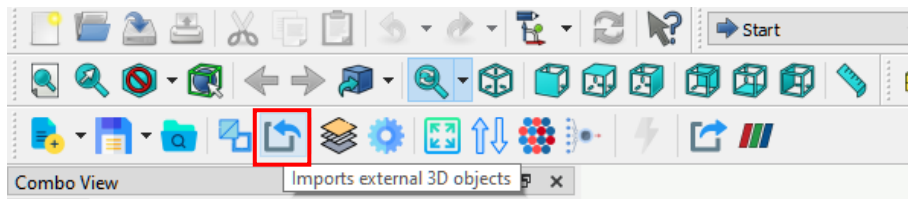
➤ **Step 1. Create a new project**

- Click the “New Project” button in the dialogue below to create a new project.
- Enter the project name and project description.

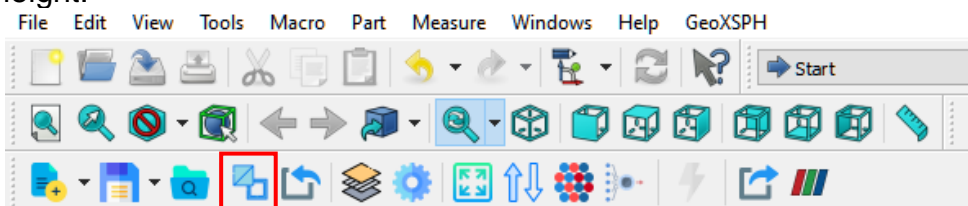


➤ **Step 2. Create initial geometry**

- Using the “Import Terrain” tool to import the mesh file for the hourglass.



- Using the “FillBox” tool to fill half of the hourglass with **sand** particles. “Fillpoint” is placed inside the top half of the hourglass, and “Filllimit” is set to a desired height.



▼ Sand	
FillLimit003	
FillPoint003	
Property	Value
Attachment	
Support	
Map Mode	Deactivated
Base	
▼ Placement	[(0.00 0.00 1.00); 0.00 °; (-5.00 mm 2.00 mm 6...
Angle	0.00 °
> Axis	[0.00 0.00 1.00]
▼ Position	[-5.00 mm 2.00 mm 67.00 mm]
x	-5.00 mm
y	2.00 mm
z	67.00 mm
Label	FillPoint003
Sphere	
Radius	10.00 mm
Angle1	-90.00 °
Angle2	90.00 °
Angle3	360.00 °

FillPoint

▼ Sand	
FillLimit003	
FillPoint003	
Property	Value
Attachment	
Support	
Map Mode	Deactivated
Base	
▼ Placement	[(0.00 0.00 1.00); 0.00 °; (-94.00 mm -87.00 m...
Angle	0.00 °
> Axis	[0.00 0.00 1.00]
▼ Position	[-94.00 mm -87.00 mm 12.00 mm]
x	-94.00 mm
y	-87.00 mm
z	12.00 mm
Label	FillLimit003
Box	
Length	200.00 mm
Width	200.00 mm
Height	85.00 mm

FillLimit

c. Similarly, Create two new “FillBox” to fill the **bottom** and the **edge** of the hourglass with boundary particles.

▼ Bottom	
FillLimit001	
FillPoint001	
Property	Value
Attachment	
Support	
Map Mode	Deactivated
Base	
▼ Placement	[(0.00 0.00 1.00); 0.00 °; (8.00 mm 2.00 mm -1...
Angle	0.00 °
> Axis	[0.00 0.00 1.00]
▼ Position	[8.00 mm 2.00 mm -120.00 mm]
x	8.00 mm
y	2.00 mm
z	-120.00 mm
Label	FillPoint001
Sphere	
Radius	10.00 mm
Angle1	-90.00 °
Angle2	90.00 °
Angle3	360.00 °

FillPoint

▼ Bottom	
FillLimit001	
FillPoint001	
Property	Value
Attachment	
Support	
Map Mode	Deactivated
Base	
▼ Placement	[(0.00 0.00 1.00); 0.00 °; (-140.00 mm -148.00 ...
Angle	0.00 °
> Axis	[0.00 0.00 1.00]
▼ Position	[-140.00 mm -148.00 mm -150.00 mm]
x	-140.00 mm
y	-148.00 mm
z	-150.00 mm
Label	FillLimit001
Box	
Length	300.00 mm
Width	300.00 mm
Height	50.00 mm

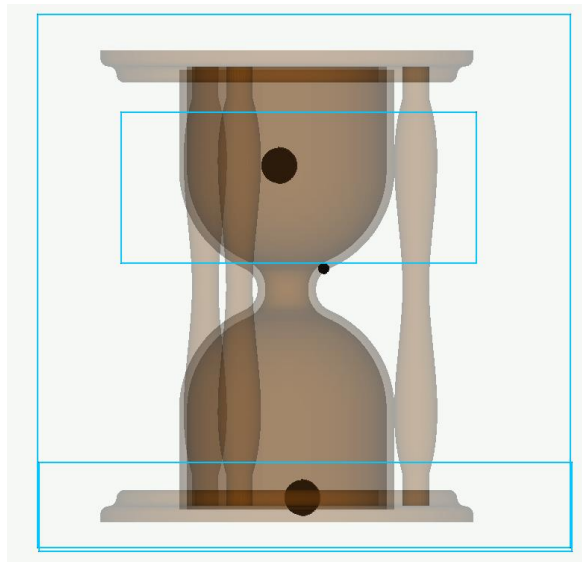
FillLimit

▼ Edge	
FillLimit	
FillPoint	
Property	Value
Attachment	
Support	
Map Mode	Deactivated
Base	
▼ Placement	[(0.00 0.00 1.00); 0.00 °; (20.00 mm 1.00 mm 9...
Angle	0.00 °
> Axis	[0.00 0.00 1.00]
▼ Position	[20.00 mm 1.00 mm 9.00 mm]
x	20.00 mm
y	1.00 mm
z	9.00 mm
Label	FillPoint
Sphere	
Radius	3.00 mm
Angle1	-90.00 °
Angle2	90.00 °
Angle3	360.00 °

FillPoint

▼ Edge	
FillLimit	
FillPoint	
Property	Value
Attachment	
Support	
Map Mode	Deactivated
Base	
▼ Placement	[(0.00 0.00 1.00); 0.00 °; (-141.00 mm -154.00 ...
Angle	0.00 °
> Axis	[0.00 0.00 1.00]
▼ Position	[-141.00 mm -154.00 mm -148.00 mm]
x	-141.00 mm
y	-154.00 mm
z	-148.00 mm
Label	FillLimit
Box	
Length	300.00 mm
Width	300.00 mm
Height	300.00 mm

FillLimit



Hint: For moving an object in 3D space. You can select the object and then go to Edit -> Transform to drag the object around.

➤ Step 3. Input SPH parameters

a. Enter the SPH parameters into the dialogue.

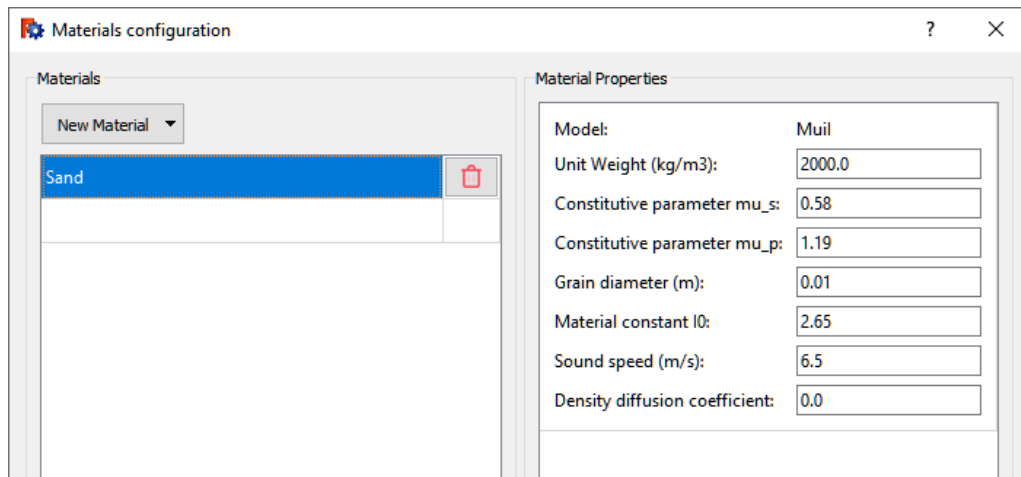


Execution parameters [?] [X]

Interaction kernel:	<input type="text" value="Cubic spline"/>
Approximation algorithm:	<input type="text" value="Type 2: <math>\sigma_i/p_i^2 + \sigma_j/p_j^2</math>"/>
Particle distance (m):	<input type="text" value="0.0018"/>
Critical timestep factor (CFL):	<input type="text" value="0.2"/>
Time out data (iter):	<input type="text" value="300.0"/>
Adaptive simulation domain:	<input checked="" type="checkbox"/>
Load initial stress:	<input type="checkbox"/> <input type="button" value="Browse"/>
Artificial stress	
Enabled:	<input checked="" type="checkbox"/>
Eps, coefficient:	<input type="text" value="0.5"/>
Particle shifting	
Enabled:	<input type="checkbox"/>
Detection algorithm:	<input type="text" value="Kernel gradient"/>
Free surface threshold(<=1):	<input type="text" value="0.8"/>
Diffusion coefficient:	<input type="text" value="2.0"/>
Artificial viscosity	
Alpha coefficient:	<input type="text" value="0.1"/>
Beta coefficient:	<input type="text" value="0"/>
Eta _c coefficient:	<input type="text" value="0.1"/>
Autostop: (For plastic Stage)	
Enabled:	<input checked="" type="checkbox"/>
Normalized velocity(v/dp) lower bound:	<input type="text" value="0.0001"/>

➤ **Step 4. Input material properties**

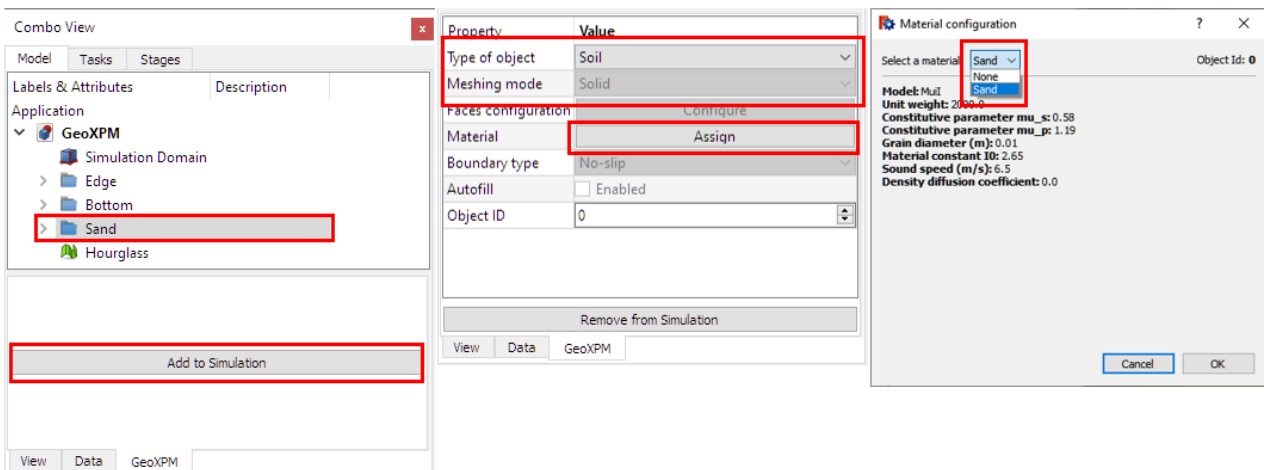
- a. Click the “Material Properties” button, select the appropriate constitutive model (i.e., $\mu(I)$ Rheology model) provided in the “New material” button, and enter the material parameters.



Hint: The timestep for the $\mu(I)$ model depends heavily on the sound speed. Setting it low makes the simulation faster but risks extreme particle overlapping and penetration. A good initial estimation for the sound speed can be induced from the maximum velocity of a free fall body ($v = \sqrt{2gH_{max}}$) times a factor of 2 to 3.

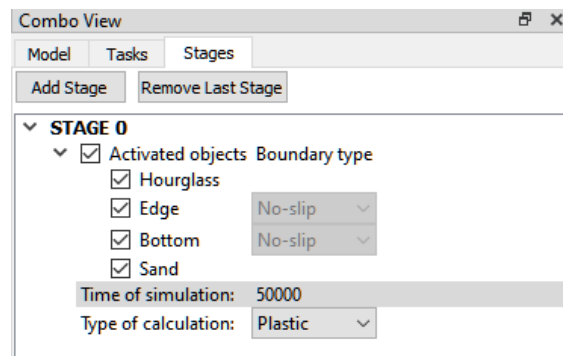
➤ **Step 5. Include objects in simulations and assign material properties**

- a. Soil object: Select the “Sand” in the “Model” tab and click “Add to Simulation” under the “GeoXPM” tab. And then, select the “Type of object” as “Soil”. In the next step, click the “Assign” button to assign the “Sand” model to the soil in the dialogue of the material configuration.
- b. Boundary object: Repeat the above process for “Hourglass”, “Edge”, and “Bottom” objects; however, keep “Type of object” as Boundary.



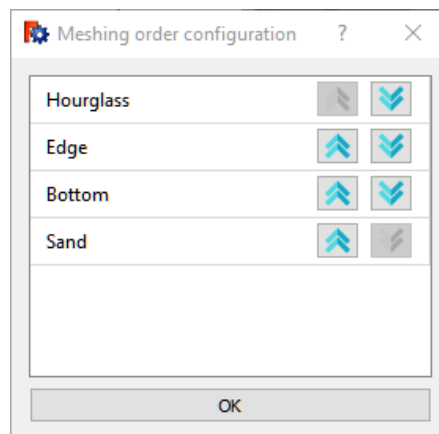
➤ Step 6. Define construction stages

- Go to the Stage tab and click “Add stage”.
- Click the checkbox “Activated objects” to activate all objects in the simulation.
- Double-click the number next to “Time of simulation” and enter 50000 steps for the elastoplastic analysis.



➤ 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.



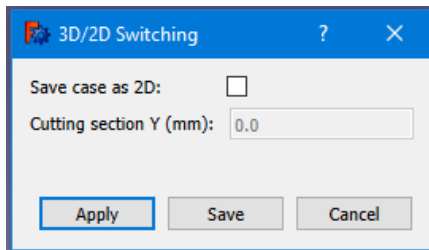
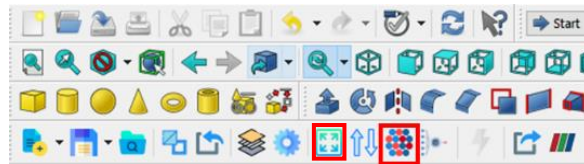
Meshing order configuration

Hint: Fillbox will fill only work after meshing a container.

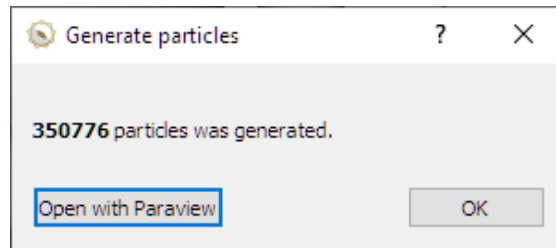
➤ Step 8. Generate particles for computations

- Before meshing, click the “Save” button () to save the project as 2D or 3D based on your need.
- Click the “Autofit simulation domain” button to fit all simulated objects in the calculation domain.
- Click the “Generate particles” tool to mesh the computational domain

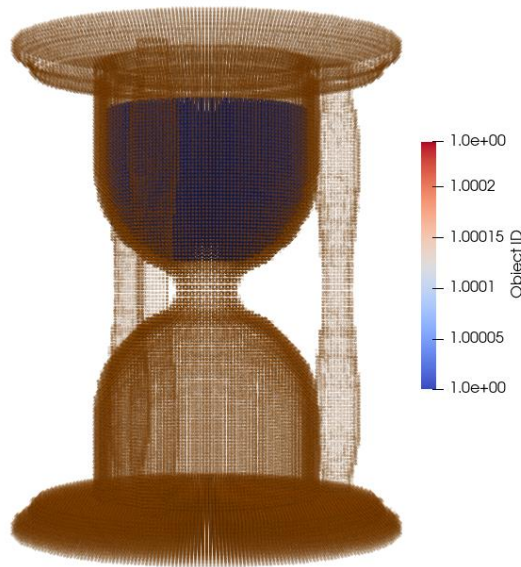
d. After meshing, click “Open with Paraview” to view the particle configuration.



Save the project as 3D



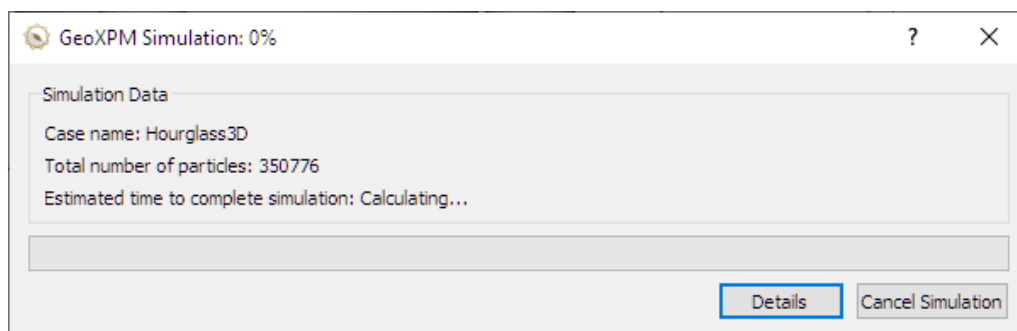
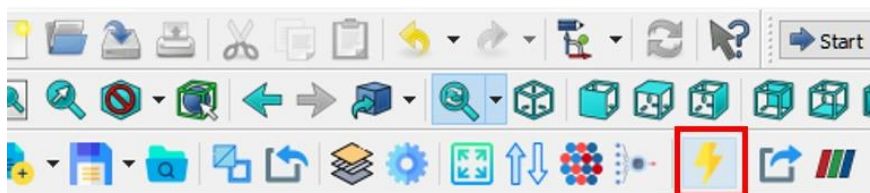
Check the particle configuration



Hint: Typically, SPH boundaries require a minimum of 2-3 consecutive layers to be effective. Inadequate thickness of the boundaries can result in them being penetrated.

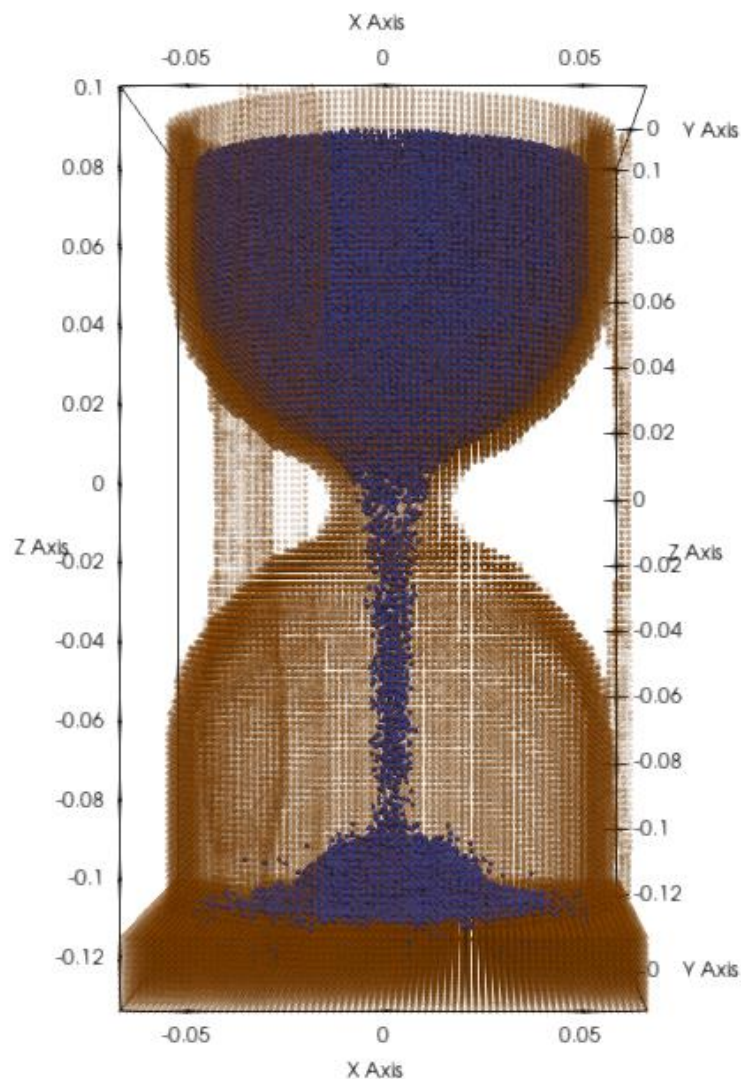
➤ Step 9. Start the Calculation

Click the “Run” button and start the calculations.



➤ Step 10. Visualisation

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




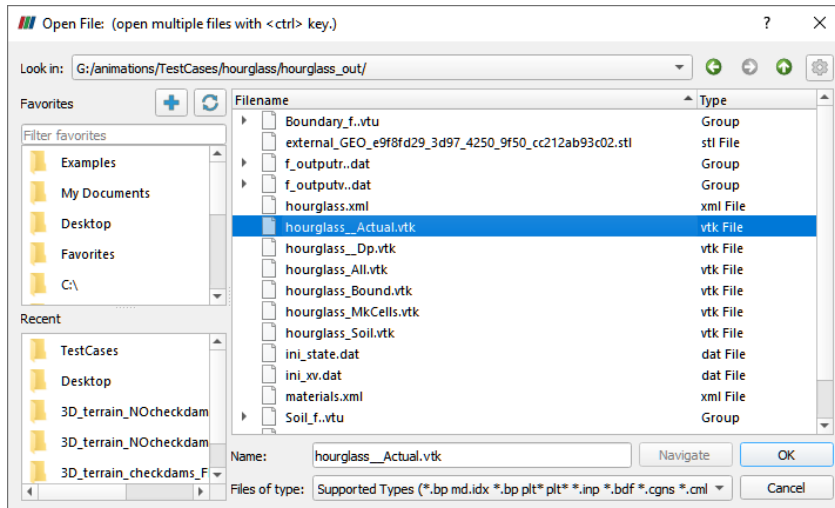
Hint: If you activate the “Adaptive simulation domain” in step 3, the simulation will only generate particles around the soil domain.

Bonus: Simple path tracer rendering in Paraview

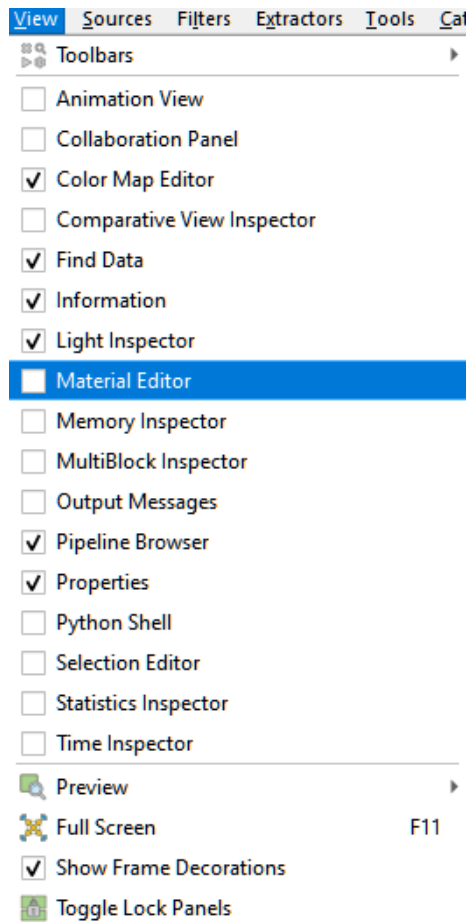
To create a rendering result. We can make use of Paraview textures and path-tracing algorithms.

- In ParaView, click the eye icon next to Boundaries in the “pipeline Browser” to hide Boundaries particles.

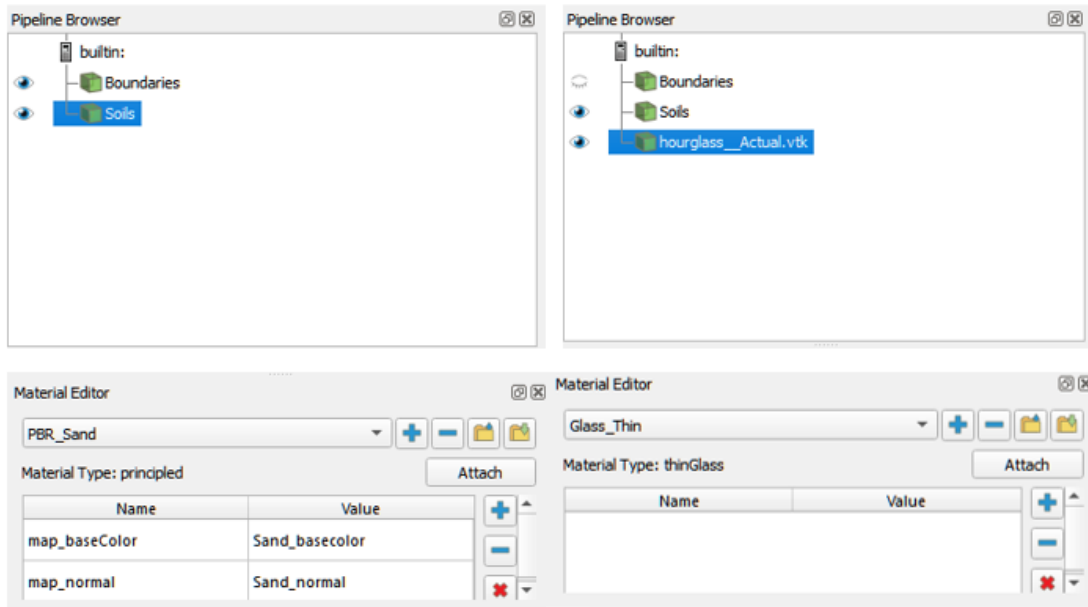
- Click “Open” button () and go to the “*_out” folder of the project, and open the “*_Actual.vtk” object.



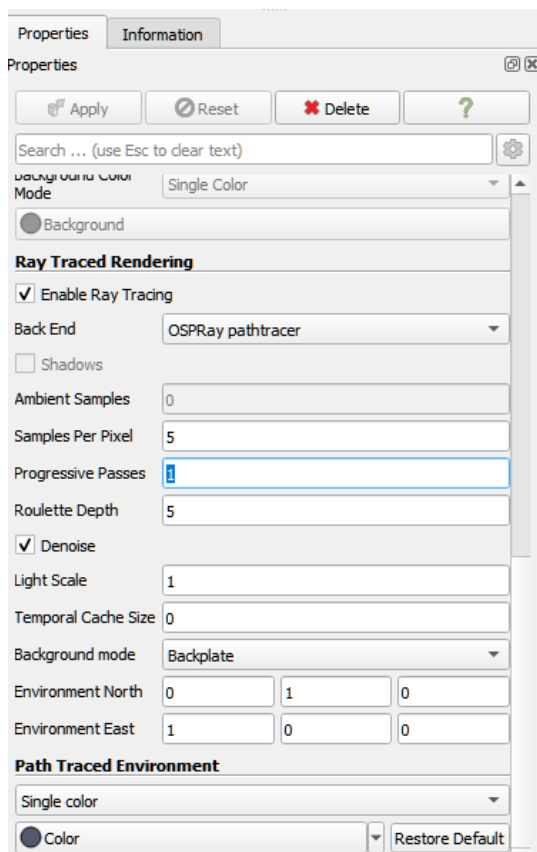
- Go to “View” Menu → Material Editor to activate the “Material Editor” tab.



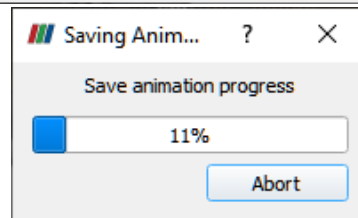
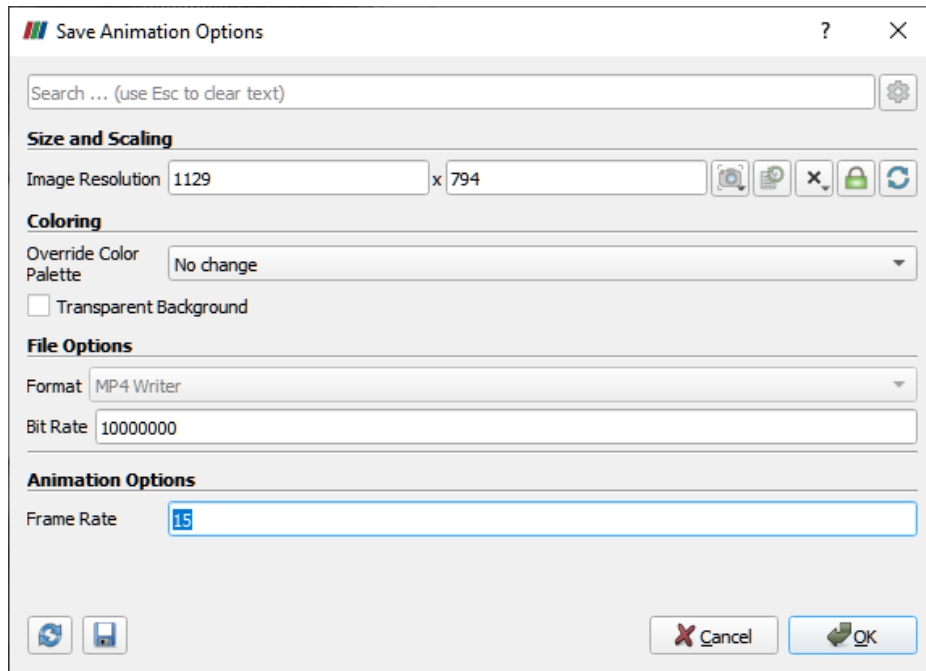
- Select the “Soils” object in the Pipeline browser → Go to the “Material Editor” tab, select “PBR_Sand”, then click Attach.
- Repeat the process in (d) for the “*_Actual” object using “Glass_Thin” material.



- f. Go to the “Properties” tab, scroll down and enable Ray Tracing.
- g. Choosing the “Back End” depends on your hardware. If you have an NVIDIA RTX graphic card, you can try “OptiX pathtracer”.
- h. Set Samples Per Pixel to 5 (higher is better but slower rendering) and background mode to Backplate.



- i. Go to “File” on the menu → “Save Animation”. In the “Save Animation Options”. Input the desired Frame Rate, Bit Rate and Resolution → Press OK and wait for the rendering to finish.



References:

1. Bui H.H, Nguyen V.T & Nguyen G.D (2023). GeoXPM: Particle-based continuum solutions for extreme geoen지니어ing, 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](#)