Seepage Through Dam

For LUSAS version:	21.0
For software product(s):	LUSAS Bridge plus or LUSAS Civil&Structural plus
With product option(s):	Geotechnical, Nonlinear

Problem Description

In this problem, we are examining the transient seepage that occurs when the water level in a reservoir on one side of an earth fill dam is raised. The base of the earth fill dam is 52 m wide. The initial steady-state reservoir level is 4 m. The flow is unconfined, with the dam built on an impermeable foundation.

Keywords

Seepage, Pore Pressure, Two Phase Material.

Associated Files

Associated files can be downloaded from the user area of the LUSAS website.

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transient_seepage.lvb carries out automated modelling of the example.

- Use File > New to create a new model of a suitable name in a chosen location.
- Use File > Script > Run Script to open the lvb file named above that was downloaded and placed in a folder of your choosing.

Objectives

The required output from the analysis consists of:

- Plotting pore pressure contours.
- □ Plotting settlement contours when the reservoir is full.

□ Plotting displacement on the downstream face of the dam during filling.

Preparing the Model Features

We create a new model, set the Analysis category as 2D, and specify the model units as kN,m,t,s,C. Timescale is set to **Days**

Feature Geometry

The dam model is created by entering point coordinates that define the dam's shape, as shown in figure 1, and then drawing lines between these points to form the surface.



Figure 1: Model geometry

Preparing the Model Attributes

Model attributes (mesh, material, geometric properties, etc.) are defined and assigned to the model. (Figure 2).



Figure 2: Model Attributes

Defining the Mesh

The surface feature is meshed using plane strain, two phase, quadrilateral, quadratic elements (QPN8P) as illustrated in figure 3. Figure 4 shows the mesh assigned to the model, a regular mesh with an elements size of 1 m.

2D Inplane			
and			
Structural			
O Element description		Regular mesh	
Element type		Allow transition patte	m
Plane strain two phase	~	Allow irregular mesh	
Element shape		Automatic	
Quadrilateral	~	🔽 Element size	1.0
Interpolation order		Local x divisions	4
Quadratic	~	Local X ambients	
		Local y divisions	4
		O Irregular mesh	
C Element name QPI	V8P	Element size	1.0
Name Dam		~	(1)

Figure 3: Surface mesh



Defining the Materials

An isotropic nonlinear material utilizing the Modified Mohr-Coulomb failure surface will be used for the sandy soil.

Table 1 gives the material properties for this example.

Table 1: material properties

Layer	Mass Density	Young's modulus, E	Poisson's ratio, v	Angle of friction, φ	Dilation	Cohesion, c
Sand	2.0 t/m ³	50.0E3 kPa	0.4	35°	35°	5 kPa

Two-phase material properties are required as well. Figure 5 gives the adopted properties and selected options. It is to be noted that hydraulic conductivity is entered in units of m/day.

Plastic 🗌 Ci	reep Damage	e 🗌 Shrinkage 🗌 Viscous 🔽 Two	o phase 🛛 🔽 Ko Initialisati
Elastic Plastic I Wo	Phase Ko Initialisation		
Fully saturated			Value
O Partially saturate	d.	Bulk modulus of fluid phase	2.2E6
-		Porosity of medium	0.5
 Water conte 	ent fraction	Hydraulic conductivity in global X direction	13.1328
Saturation		Hydraulic conductivity in global Y direction	13.1328
Draining/filling of	upus definition	Hydraulic conductivity in global Z direction	13.1328
Draining/mining C	urve demnidori	Density of fluid	1.0
Constant water	content ~	Saturation at residual water contents	0.0
		Saturation at full water contents	1.0
Absolute value	um suction pressure um cavitation pressure		
Name	e Dam		 ✓ ▲ (2)

Figure 5: Two-Phase properties

Defining the Supports

Fully fixed supports are assigned for the base of the dam (Figure 4). Seepage boundary conditions are required on the downstream slope of the dam which are defined by selecting the **Seepage** radio button on the **Structural Supports** dialog (figure 6).

uctural Supports						
Analysis category 2D	Inplar	ne				
		Free	Fixed	Spring	Spring stiffness	Contact
	x	۲	0	0		0
Translation in	Y	۲	0	0		0
	z	۲		0		
	x	۲		0		
Rotation about	Y	۲		0		
	z	۲	0	0		0
Hinge rotation		۲		0		
Torsional warping		۲		0		
		Closed S	eepage Draina	ige Open	Pressure	
Pore pressure		0	• •	0		
Spring stiffness distribu Stiffness Stiffness/unit lengt Stiffness/unit area Lift-off >> No contact << Non-reflective >>	th					
Name Seepa	ige Bou	undary Cond	ditions		✓ ↓ (1)	

Figure 6: Seepage boundary conditions

Defining Loads and Phreatic Surface

To simulate changes in the water level in the reservoir, we establish the phreatic surface using the command: **Attributes > Pore Water Pressures > Phreatic Surface**. This attribute is then applied to a line feature as depicted in figure 7. As the water level rises, this line will move upward. To achieve this, we apply a displacement of 6 m in the Y direction to the line using the command **Attributes > Loading > Prescribed Displacement** (Figure 6). Finally, to calculate and obtain the water pressure distribution from the established phreatic surface, we create a water pressure distribution attribute using the command **Attributes > Loading > Water Pressure Distribution** and link it to the previously established Phreatic Surface attribute (Figure 8).



Figure 7: Assigning phreatic surface

Self-weight is to consider by right-clicking on the load case in the Treeview and selecting the **Gravity**.

Water Pressure Dist	ribution		\times
Analysis category	2D Inplane		
Pressure profile			
O Calculated from	phreatic surface	e, assigned to faces	
Ph	reatic surface	2:Upstream V	
		Density of fluid	
		Set only porewater pressure	
O Fully defined by	profiles, assigne	ed to continuum	
Pi	ofile variation	3:Water Profile 🗸	
Name Ups	tream Water Pr	ressure V (3)	
	Close	e Cancel Apply Help	

Figure 8: Water pressure distribution

Running the Analysis

We consider two construction stages.

Initial Phase

This stage simulates the initial conditions where we have the initial level of water level of 4 m. Nonlinear analysis control properties are defined for this phase, the number of iterations which is increased to 20 as the initial stage takes longer to convergence than normal and line searches are switched off (figure 9).

data di secolo d		Solution strategy	
Nonlinear		Same as previous loadcase	-
Incrementation	Manual ~	Max number of iterations	20
Starting load factor	0.1	Residual force norm	0.1
Max change in load factor	0.0	Incremental displacement norm	1.0
Max total load factor	1.0		Advanced
Adjust load based on co	nvergence	Incremental LUSAS file output	
Iterations per increment	4	Same as previous loadcase	
	Advanced	Output file	1
Time domain		Plot file	1
	Two Phase \sim	Destart file	0
Initial time step	0.0	Restart file	
Total response time	100.0E6	Max number of saved restarts	0
Automatic time stepping		Log file	1
	Advanced	History file	1
		Save a restart at the end of this	control
ommon to all			
Max time steps o	r increments 0		

Figure 9: Increase maximum number of iterations

Rising Water Level

Using the **Prescribed Displacement**, we raise the water level in the reservoir up to 10m.

Viewing the Analysis

Analysis loadcase results are present in the Treeview.

Pore Pressure

Pore pressure contours for the final phase are drawn in figure 10.



Figure 10: Pore pressure contour (water level at 10 m)

Downstream Displacement

Figure 11 shows the resultant displacement when the reservoir is full whilst the displacement at point A is plotted in figure 12.



Figure 11: Resultant displacement (water level at 10 m)



Figure 12: Resultant displacement in function of water level at point A