GEO-SLOPE | Direct Contact January 2006

In this issue:

New Year's Greetings
Unit Gradient Boundary Condition

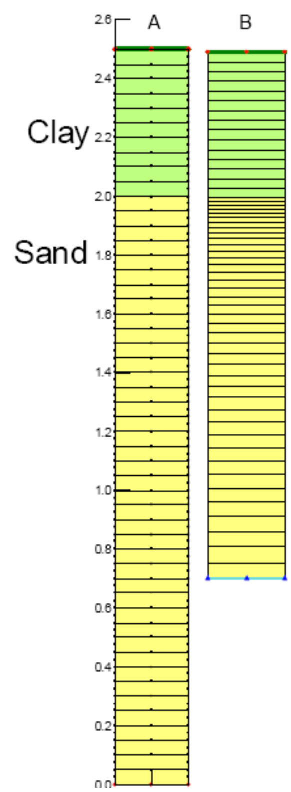
New Year's Greetings

We at GEO-SLOPE trust that you had an enjoyable and relaxing holiday season and are looking forward to a successful 2006. This past year has been a record-breaking year for GEO-SLOPE, and we wish to thank you, our clients, for placing your trust and confidence in us. We are excited about the prospects for 2006, particularly regarding our new software developments that we have underway. We look forward to sharing these with you later this year.

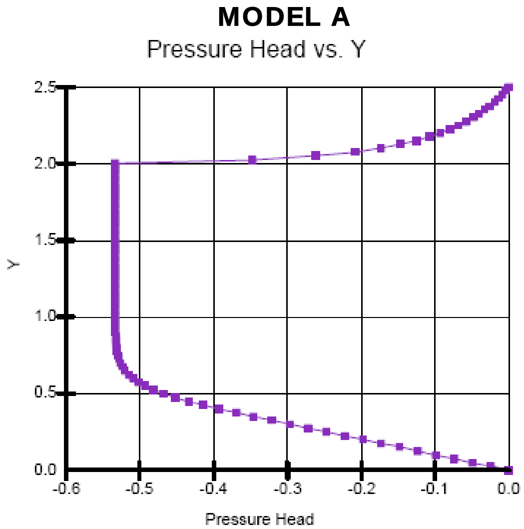
Best wishes for the New Year from all of us at GEO-SLOPE.

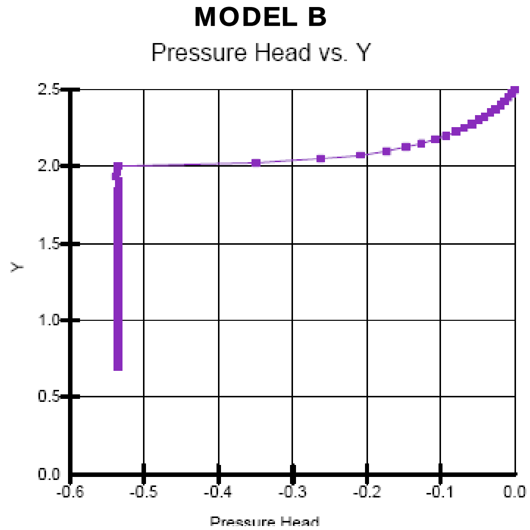
Unit Gradient Boundary Conditions in Seepage Modeling

When doing seepage modeling using SEEP/W it is necessary to define either the flow or pressure boundary condition at the base of the model. In many cases a "no flow" condition can be assumed, but this is not true when modeling infiltration at the ground surface or through pond liners or soil cover systems. In these cases the underlying pore-water pressure conditions will have a direct influence on the infiltration rates through the ground. It would be nice to always be able to conduct an analysis such that the ground water table was at, or near the base of the model. However, sometimes the water table is located deep within the profile or, as is often the case, its elevation is simply not known. Under certain circumstances it is possible to use a unit gradient boundary condition to model these difficult conditions where neither the pressure nor the flow rate at the bottom of the profile is known in advance.



Consider the two profiles on the right which show a clay liner over a more coarse sand base material. In this case, infiltration rates through the clay liner and the resulting pressure profiles within the underlying sand material are of interest. In both Model A and Model B, a zero pressure boundary condition has been applied to the top of the model. This means that there is ample water available to maintain saturation at the top of the profile. The base boundary condition at the bottom has been modeled differently in each simulation. Model A is larger and represents a deeper profile. There is a ground water table at the base of the profile so a pressure head boundary condition of zero has been defined along the bottom of the mesh. The assumption for Model B is that the water table is located at an elevation further below the bottom of the modeled profile, so a unit gradient boundary condition has been applied at the bottom of the mesh instead of a pressure boundary condition. The resulting pressure profiles for the two simulations are shown below.





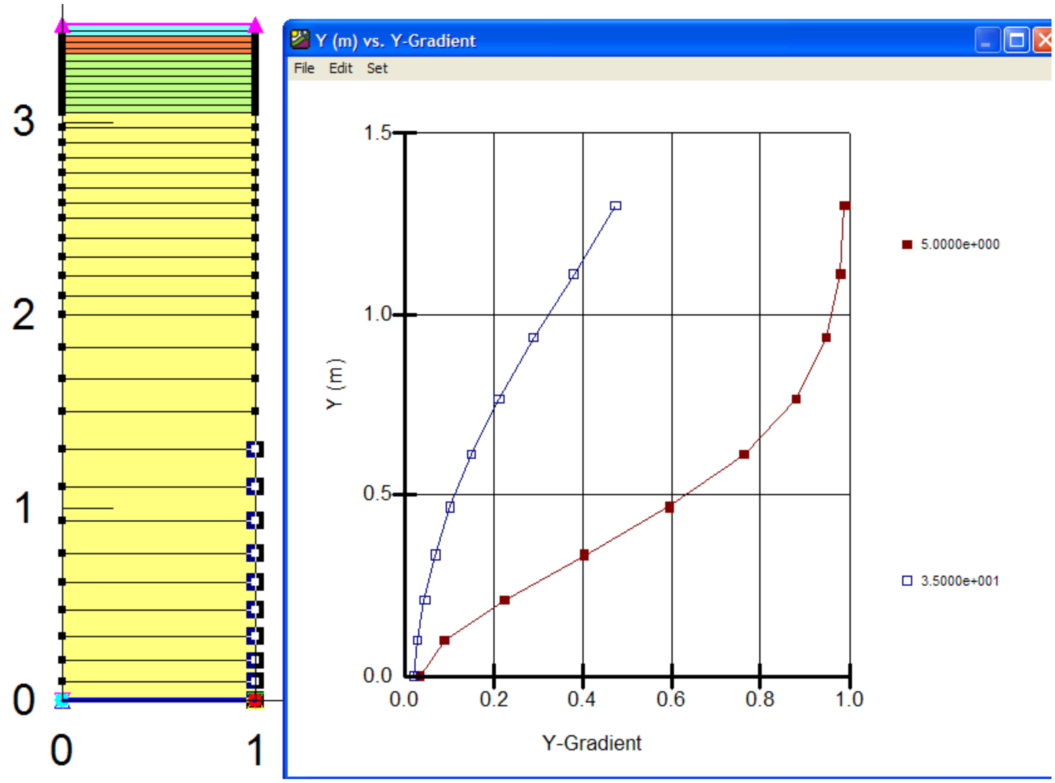
The pressure profile for Model A (left), shows that the pore-water pressures are negative throughout both the clay liner and the underlying sand material, with the exceptions being right at the top and bottom boundary nodes where the user specified P=0 condition was applied. In Model B (right), which had the applied unit gradient defined at the bottom, the pressure profile is the same as that of Model A. The models show the same residual pressure profile developing in the sand layer and they have the same computed flow rates through the clay liner. The only difference is that the dissipation of pore-water pressures at the bottom of the sand layer have not been modeled in Model B. The unit gradient boundary condition placed at an appropriate depth beneath the liner was able to model the correct steady state pore-water pressure profile within the sand, and the computed infiltration rates through the clay liner are identical for both simulations.

How can you tell where to put the unit gradient?

By definition, a unit gradient exists when the change in total head will be equal to the change in elevation (i.e., $i = 1.0$). This means that the pore-water pressures will be constant with elevation. If the gradient is equal to unity, then for steady state conditions we know based on Darcy's Law that the unit flow rate, q, will be equal to the unsaturated hydraulic conductivity, k, that corresponds to the pore-water pressure condition existing in the soil.

The key to proper application of a unit gradient boundary condition is to place it far enough beneath the ground surface, soil cap or pond liner such that the flow conditions at that point are no longer changing and the pressures are constant, not transitional. Even in a transient analysis the unit gradient must be placed at a point where the flow is under pseudo steady-state conditions. In Model B shown above, the analysis was steady state so placement of the unit gradient boundary condition was not as critical and it only had to be placed at a depth where the pressures would not be changing. For a transient analysis, deciding where to place the unit gradient boundary condition can be more difficult.

The figure below shows a soil cover system being modeled where changes to the water storage and flow within the cover over time are being predicted. The corresponding graph shows the gradient profiles near the bottom of the mesh after 5 and 35 days of the analysis. It is apparent that the gradient in the lower part of the profile does not remain constant over time. This is because the lower boundary condition was placed too close to the surface and constant drainage conditions through the lower part of the profile have not been established. In other words, flow in the bottom soil layer is still responding to changing flow rates and changes in the stored water within the upper soil profile. To determine if the unit gradient boundary condition has been appropriately used, simply plot gradient profiles at different time steps to see if they remain at unity or if they change over time. The problem is easily resolved by extending the profile, moving the boundary condition lower, and rerunning the analysis.



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