# Air Flow Modeling with

# AIR/W 2007

An Engineering Methodology

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# 1 Introduction

AIR/W is a module that runs inside the SEEP/W program where it solves for air pressure and flow in response to pressure boundary conditions or changes in water pressure. If coupled with TEMP/W, then AIR/W also solves for thermally induced density dependent air movement and pressure changes.

Unsaturated soil mechanics has, as it primary stress state, a variable known as matric suction. Matric suction is composed of two parts: air pressure and water pressure; and is computed as the difference between these two (Ua – Uw). Traditional seepage models have assumed that the air component is atmospheric such that the matric suction reduces to the negative value of water pressure, -Uw. This is the case when using SEEP/W alone and this is a valid assumption in many applications. However, it is a limiting assumption for a wide range of engineering problems – which is the topic of this book.

## *1.1 Typical applications*

Air pressure and flow in soils has significance in many engineering problems. Some of these include:

- Air pressures in tunneling for support and seepage control
- Air pressure build up in advance of wetting fronts (Lisse Effect)
- Air flow and convective heat transfer in arctic roads, railway embankments, and mine waste rock piles where permafrost is jeopardized
- Air flow for soil contaminant vapor extraction systems
- Air flow in landfills and mine waste dumps where air feeds biological breakdown of waste

## *1.2 About this book*

Modeling the movement of air through soil with a numerical solution can be very complex. Natural soil deposits are generally highly heterogeneous and non-isotropic. In addition, boundary conditions often change with time and cannot always be defined with certainty at the beginning of an analysis. In fact, the correct boundary condition can sometimes be part of the solution as is the case for an air pressure exit review boundary, where air release may be impeded if water begins ponding on the ground surface.

The movement of air cannot be modeled without a valid model for groundwater flow in the system. That is why AIR/W is a module within SEEP/W and not a product on its own. The flow of water and air are inseparable. This book is NOT about seepage modeling and it is assumed from this point onward, that the reader is familiar with and has read the SEEP/W Engineering Methodology book. This book is not a stand-alone reference. It is about taking seepage and thermal modeling to the next level…. by including air pressure and air flow.

While part of this document and the SEEP/W book are about using AIR/W to do air flow analyses, they are also about general numerical modeling techniques. Numerical modeling, like most things in life, is a skill that needs to be acquired. It is nearly impossible to pick up a tool like AIR/W and immediately become an effective modeler. Effective numerical modeling requires some careful thought and planning and it requires a good understanding of the underlying physical fundamentals. Aspects such as discretization of a finite element mesh and applying boundary conditions to the problem are not entirely intuitive at first. Time and practice is required to become comfortable with these aspects of numerical modeling.

Chapter 2 of the SEEP/W book is devoted exclusively to discussions on the topic of How to Model. The general principles discussed in that book apply to all numerical modeling situations, even though the discussion there focuses on seepage analysis.

Broadly speaking, there are three main parts to a finite element analysis. The first is discretization – dividing the domain into small areas called elements. The second part is specifying and assigning material properties. The third is specifying and applying boundary conditions. Details of discretization are provided in the SEEP/ book, while material properties and boundary conditions as pertaining to air flow analysis are discussed in detail in their respective chapters here.

Air flow modeling is numerically challenging when coupled with thermal modeling because of the presence of a first order transport term in the main thermal differential equation. For this reason, it is important to have an understanding of how that term affects the solution of the equations and, in particular, how mesh size and time steps are critical to that solution. The importance of the Courant numbers will be introduced and discussed, along with other numerical considerations in a chapter titled Numerical Issues.

One chapter has been dedicated to presenting and discussing illustrative examples.

A full chapter is dedicated to theoretical issues associated with air flow and the solution the seepage, air and thermal finite element equations. Additional finite element numerical details regarding interpolating functions and infinite elements are given in Appendix A of the SEEP/W and TEMP/W books.

The chapter entitled “Modeling Tips and Tricks” should be consulted to see if there are simple techniques that can be used to improve your general modeling method or to help gain confidence and develop a deeper understanding of finite element methods, AIR/W conventions or data results.

In general, this book is not a HOW TO USE AIR/W manual. This is a book about how to model. It is a book about how to solve air flow problems using a powerful calculator; AIR/W. Details of how to use various program commands and features are given in the on line help inside the software.