

# Stress-Deformation Modeling with SIGMA/W 2007

An Engineering Methodology

Third Edition, March 2008

GEO-SLOPE International Ltd.

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Printed in Canada.

GEO-SLOPE International Ltd  
1400, 633 – 6<sup>th</sup> Ave SW  
Calgary, Alberta, Canada T2P 2Y5  
E-mail: [info@geo-slope.com](mailto:info@geo-slope.com)  
Web: <http://www.geo-slope.com>

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# 1 Introduction

SIGMA/W is a finite element software product that can be used to perform stress and deformation analyses of earth structures. Its comprehensive formulation makes it possible to analyze both simple and highly complex problems. For example, you can perform a simple linear elastic deformation analysis or a highly sophisticated nonlinear elastic-plastic effective stress analysis. When coupled with other GEO-SLOPE software products, it can also model the pore-water pressure generation and dissipation in a soil structure in response to external loads using either a fully coupled or un-coupled formulation. SIGMA/W has application in the analysis and design for geotechnical, civil, and mining engineering projects.

## 1.1 Applications

SIGMA/W can be used to compute stress-deformation with or without the changes in pore-water pressures that arise from stress state changes. In addition, it is possible to model soil structure interaction using beam or bar elements. The following are some typical cases that can be analyzed using SIGMA/W.

### ***Deformation analysis***

The most common application of SIGMA/W is to compute deformations caused by earthworks such as foundations, embankments, excavations and tunnels. Figure 1-1 shows a typical case of a fluid-filled tank on the ground surface. This figure presents the deformation at an exaggerated scale as a deformed mesh. Figure 1-2 shows the associated change in vertical stress in the ground caused by the applied load.

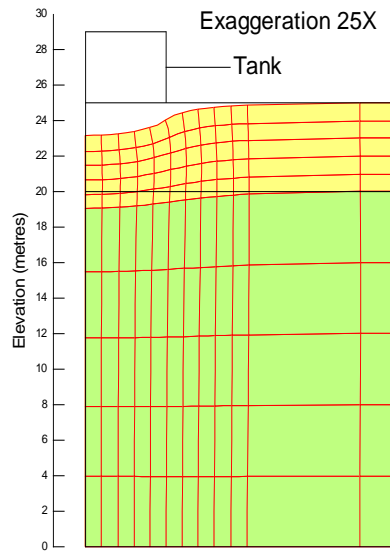


Figure 1-1 Deformation under a fluid-filled tank

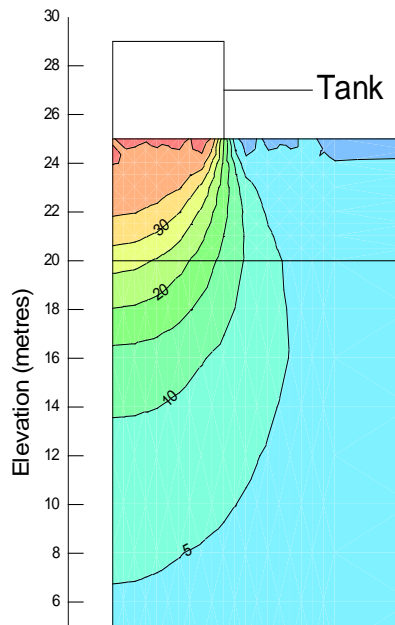
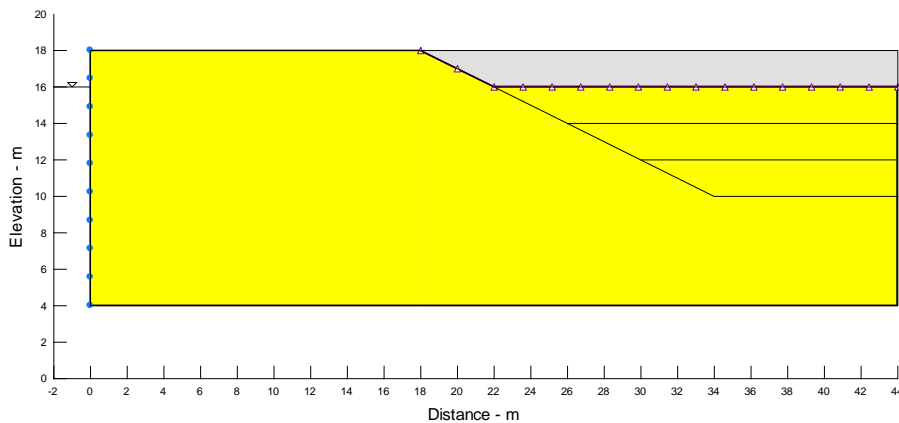


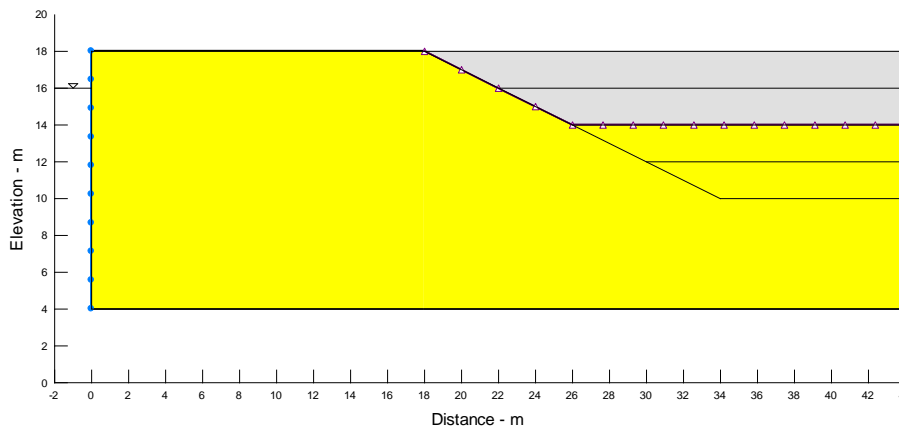
Figure 1-2 Vertical stress change under a fluid-filled tank

### ***Staged construction***

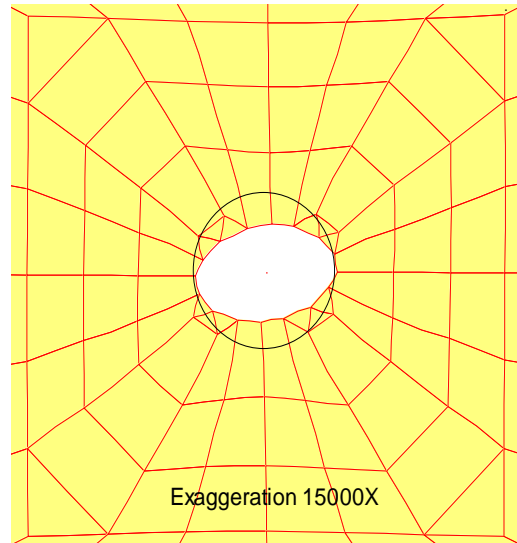
Soil regions can be activated or deactivated at different stages in a project file, making it possible to simulate the process over time. New in GeoStudio 2007 is the concept of multiple analyses in a single project file. By automatically linking these analyses together on a common time continuum, you can simulate construction sequences. You can also apply boundary conditions that move with time. Figure 1-3 shows the sequencing of excavation and lowering seepage face location. Figure 1-5 shows the closure around a tunnel in anisotropic linear-elastic material.



**Figure 1-3 First excavation and lowered hydraulic BC**



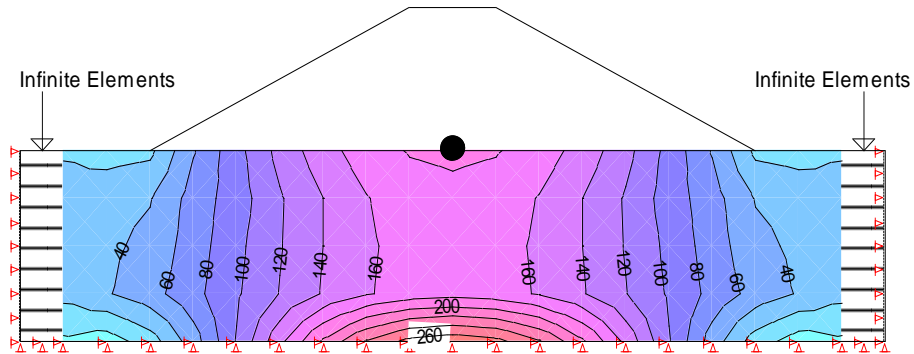
**Figure 1-4 Second excavation and lowered hydraulic BC**



**Figure 1-5 Closure around a tunnel**

### ***Excess pore-water pressures***

The effect of excess pore-water pressures generated during fill placement is often a major consideration in slope stability during construction. SIGMA/W can be used to estimate these types of pore-water pressures. Excess pore-water pressures computed using SIGMA/W may be imported into SLOPE/W for slope stability analysis. Figure 1-6 shows the excess pore-water pressures in the foundation beneath an embankment immediately after construction. Note the use of infinite elements for modeling the right and left boundaries.



**Figure 1-6 Excess pore-water pressures caused by fill placement**

### ***Soil-structure interactions***

SIGMA/W can accommodate soil-structure interaction problems by including structural elements in two-dimensional plain strain analyses. These elements can be beam elements which have flexural stiffness, or bar elements which have only axial stiffness with no flexural stiffness. These structural elements are particularly useful when analyzing cases such as sheet-pile walls. Figure 1-7 illustrates the deformation for such a case, and Figure 1-8 shows the associated moment distribution in the sheet-pile wall.

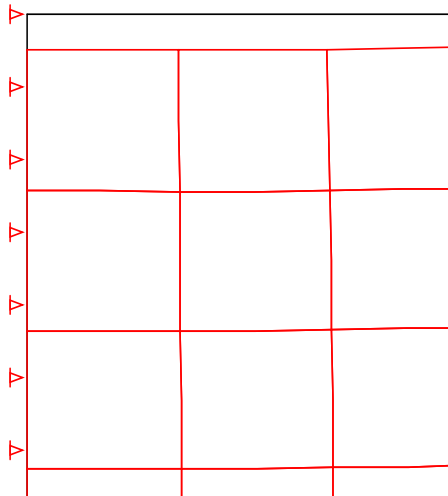


Figure 1-7 Sheet pile wall example

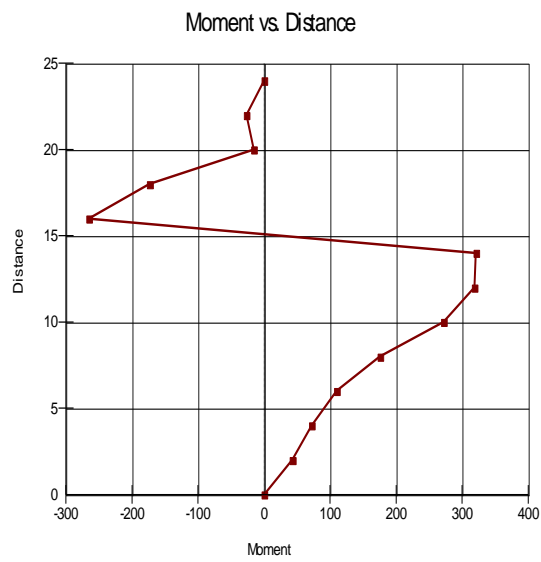
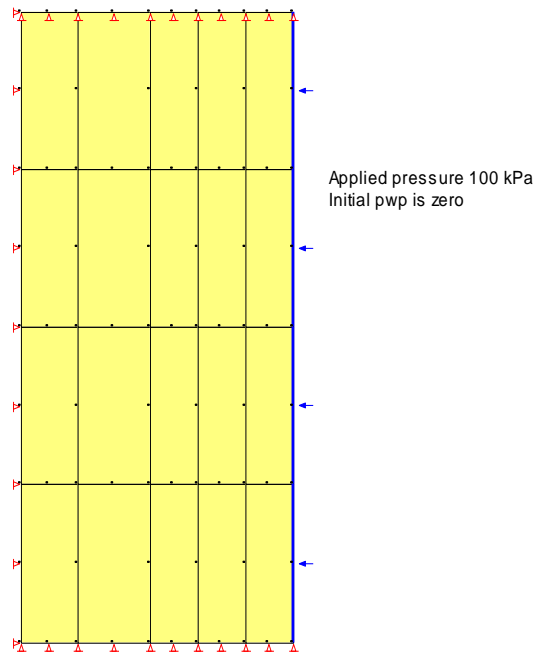


Figure 1-8 Moment distribution in a sheet pile wall

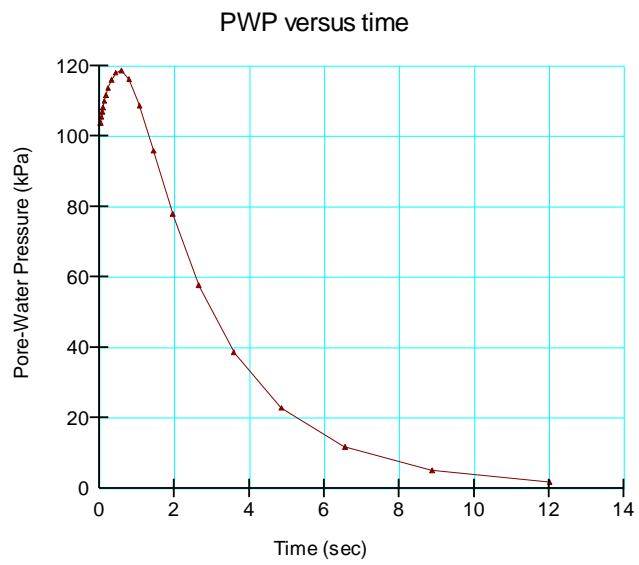
### **Consolidation analyses**

SIGMA/W can be used together with SEEP/W to perform a fully-coupled consolidation analysis. When these two integrated products are run simultaneously, SIGMA/W calculates the deformations resulting from pore-water pressure changes while SEEP/W calculates transient pore-water pressure changes. This procedure is used to simulate the consolidation process in both saturated and unsaturated soils.

A fully-coupled analysis is required to correctly model the pore-water pressure response to an applied load. In certain cases, the pore-water pressure increase under an applied load can be greater than the applied load. This phenomenon is known as the Mendel-Cryer effect. Figure 1-9 shows a SIGMA/W analysis of a saturated triaxial sample with an applied lateral load of 100 kPa. The initial pore-water pressure before loading is zero. Figure 1-10 shows the pore-water pressure response with time at the center of the sample. The pore-water pressure rises to about 110 kPa, (110% of the applied load), before it gradually decreases.



**Figure 1-9 Tri-axial sample with applied lateral load**



**Figure 1-10 Pore-water pressure change with time**

