MATHEMATICAL BASIS OF REM PROGRAM CODE

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1.0 INTRODUCTION

The design of solution caverns and analysis of storage operations have been dependent on the application of the finite element method of analysis. The finite element method is a powerful means of designing and analyzing various manmade structures such as spaceships, skyscrapers, bridges, and dams. It is, however, extremely difficult to apply this method to geological structures in general and solution caverns in particular, primarily because the geomechanical properties of earth materials are usually uncertain and site-specific, especially under three-dimensional confinement. In spite of a large amount of government-supported research conducted during the past 20 years, the geomechanical behavior of rock salt has not been adequately defined to make the finite element method readily applicable.

In general, the technology associated with the finite element method has been well established for immediate use. The necessary computer hardware and software are readily available for various applications at reasonable cost, as listed below:

Item	Component	Price Range
Computer hardware	PC 486/33 MHz	$ 4,000 ~ $10,000
Peripherals	Plotter and printer	3,000 ~ 5,000
Supporting software	OS/2, GSS, AutoCad, etc.	3,000 ~ 4,000
FEM code (e.g., Desai, 1979)	Numerical analysis software	5,000 ~ 10,000
Constitutive equation	Elastoplastic theory, creep law	0 ~ ∞

In applying the method to solution cavern design, a serious problem arises: the constitutive equations available in the market are not sufficiently realistic and are often misleading. To rectify this situation in solution mining work, SGI has developed a constitutive equation of salt. SGI's equation is not based on the idealized theory of material behaviors, such as elastoplastic theory and creep law, but rather is synthesized from basic behavioral components which have been identified from long-term observation of underground salt mines and solution caverns (Serata et al., 1989; Dickie et al, 1986; Serata, 1984). Seven behavioral components are used in the synthesis: elasticity, viscoelasticity, viscoplasticity, volumetric expansion, thermal expansion, brittle-ductile failure, and postfailure deterioration. Thus, the equation "REM" is different from all other constitutive equations in its basic concept.

This paper describes the method of synthesizing the constitutive equation. The basic behavioral components are identified and their mathematical formulations are explained. The reasons why the REM constitutive equation can so closely simulate brittle-ductile behavior are also explained.