Numerical Modelling of Gas Injection Experiment Using Damage Model

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1. Introduction

In the case of a repository for radioactive waste, corrosion of ferrous materials under anoxic conditions lead to the formation of hydrogen, carbon dioxide, hydrogen sulphide and methane [1]. If the gas production rate exceeds the gas diffusion rate in the pores of the engineering barrier, the pressure of the gas continuously increases and sudden gas flow occurs when the specific pressure is reached. Since the concept of the porous medium considering the existing two-phase flow is inadequate to simulate this phenomenon, it is necessary to develop a new numerical model for gas migration in the low permeability layer. Therefore, in this study, we developed a gas migration model using mechanical damage model and compared the results of laboratory gas injection experiment and numerical analysis.

2. Numerical model

2.1 Mechanical damage model

In order to model the gas migration phenomena, we adopted elastic damage model by Tang et al. [2]. In this model, the elastic modulus of the element may degrade gradually as damage progresses, and the elastic modulus of the damaged element is defined as follows:

$$E=(1-D)E_0 \quad (1)$$

where D represents the damage variable, and E and E_0 are the elastic moduli of the damaged and undamaged elements, respectively.

2.2 Gas injection experiment

BGS conducted a 1D gas flow test on pre-compacted bentonite subject to a constant volume boundary condition. Fig. 1 shows schematic view of gas injection experiment. The test is comprised of a two stages; sample hydration and gas injection. Gas was injected with constant flow rate, so gas pressure gradually increased. After gas breakthrough, the injection pump was stopped and the pore water pressures decreased substantially.

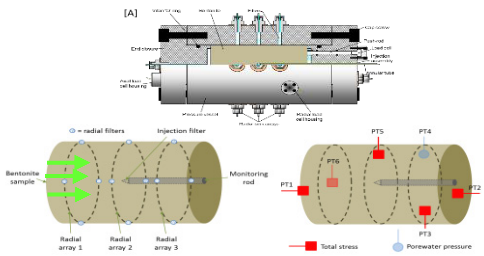

Fig. 1. Schematic view of 1D gas injection experiment [3].

2.3 Properties

Table 1 shows properties of bentonite. Elastic modulus, Poisson ratio, porosity, and permeability are given properties. Other mechanical and hydraulic properties are issued by references except damage model properties.

Table 1. Properties of bentonite

Properties		Bentonite
Elastic model	Elastic modulus (Pa)	3.07E+08
	Poisson ratio	0.4
Damage model	Tensile strength (Pa)	1.00E+06
	Residual tensile strength (Pa)	2.00E+05
	Compressive strength (Pa)	1.20E+6
	Residual compressive strength (Pa)	3.00E+6
	Tensile strain limit	5.00E-03
Biot coefficient		0.862
Porosity (-)		0.44
Intrinsic Permeability (m^2)		3.40E-21

3. Results

Fig. 2 shows pore pressure evolution at injection filter and back pressure filter. Pore pressure increase dramatically due to the damage of bentonite. The trend of peak and post-peak pressure is well matched, however, timing of increase to the peak is different because damage of bentonite is occurred gradually from injection filter to backpressure filter.

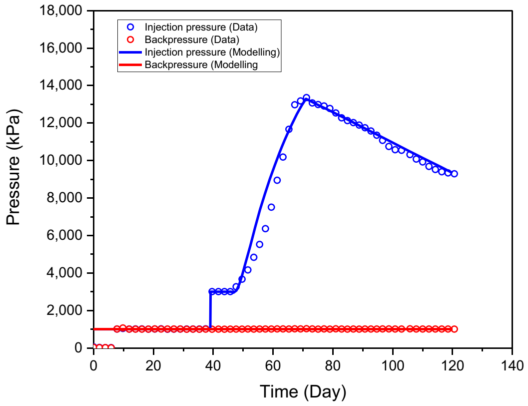

Fig. 2. Pore pressure evolution at injection filter and back pressure filter.

Fig. 3 shows damage evolution. Damage evolves from injection filter to backpressure filter. Increase of pore pressure induces decrease of effective stress. If effective stress is less than the tensile strength, damage is occurred. Damage is not observed near the stainless steel tube because stainless steel tube has relatively high elastic modulus.

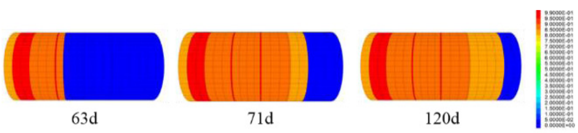

Fig. 3. Damage evolution.

4. Conclusion

For modelling about gas migration, we developed a gas migration model using mechanical damage model and compared the results of laboratory gas injection experiment and numerical analysis. In general, Pore pressure results are well matched. The trend of peak and post-peak pressure is well matched, however, timing of increase to the peak is wrongly predicted. Damage evolves from injection filter to backpressure filter similar with pore pressure increase.

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