MODELING OF FLOW THROUGH FRACTURED TUFF AT FRAN RIDGE

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I. INTRODUCTION

Numerical studies have modeled an infiltration experiment at Fran Ridge, using the TOUGH2[1] code, to aid in the selection of computation models for waste repository performance assessment. This study investigates the capabilities of TOUGH2 to simulate transient flows through highly fractured tuff, and provides a possible means of calibrating hydrologic parameters such as effective fracture aperture and fracture-matrix connectivity. Two distinctly different conceptual models were used in the TOUGH2 code, the dual permeability model and the equivalent continuum model. The field experiments involved the infiltration of dyed ponded water in highly fractured tuff. The infiltration observed in the experiment was subsequently modeled using Fran Ridge fracture frequencies, obtained during post-experiment site excavation. Comparison of the TOUGH2 results obtained using the two conceptual models gives insight into their relative strengths and weaknesses.

II. FRAN RIDGE FIELD EXPERIMENT

A major outcrop of densely welded, nonlithophysal Topopah Springs Tuff exists on the eastern side of Fran Ridge. This ridge was selected as the test location for a large *in situ* block experiment. An integral part of preparation of the ridge for the large block experiment called for the removal of the surrounding country rock such that a 4.5 m high and 3 m x 3 m test block remained. Prior to excavating the region adjacent to the large block, 0.78 m^3 of blue dyed water was ponded in a 1.5 m diameter region on a leveled surface of the surrounding country rock and allowed to infiltrate the subregion. The infiltration process took 36 minutes. The removal of the country rock, in approximately 0.5 m thick layers, provided an opportunity to map the *in situ* rock fracture network and the infiltration paths of the water in a 2.4 m by 2.4 m by 4.5 m deep region. The blue tracer dye used in the experiment indicated ample fracture flows down to the 4.5 m depth. This experiment and the associated mapping was completed by Nicholl and Glass2.

III. NUMERICAL APPROACH

The region modeled using the TOUGH2 code is given in Figure 1. The heterogeneous distribution of fracture frequency within the inner core was measured for 640 individual 0.30 x 0.30 x 0.46 m blocks from fracture maps. These values of fracture frequency were used to obtain material properties employed in the dual permeability and equivalent continuum models. An average of these experimentally observed core fracture frequencies was used to obtain material properties for the surrounding buffer region, Figure 1. A total of 2016 matrix elements and an additional 2016 fracture elements were used.

An infiltration rate of 0.85 m^3 in 36 minutes was calculated for this base case using the dual permeability model and an assumed fracture aperture of 285 μm. This infiltration rate agreed to within 10% of the experimentally observed value of 0.78 m^3. Water infiltrated the fractures such that the calculated fracture saturation was greater than 0.5 to a depth of 40 m, Figure 2. When the inner heterogeneous core was modeled with a homogeneous average of the experimentally measured fracture frequencies and the dual permeability model, the calculated infiltration decreased to 0.73 m^3.

When the equivalent continuum model was used, the calculated infiltration increased to 1.90 m^3. This is 2.4 times greater than the observed value of 0.78 m^3. However, the penetration depth of the infiltrating water was significantly less than that calculated using the dual permeability model, Figure 2.

In order to determine the sensitivity of infiltration rate and water distribution within the tuff, variations of the base case were calculated by varying the specified fracture aperture, matrix permeability, matrix/fracture connectivity, and degree of heterogeneity.

IV. CONCLUSIONS

The numerical investigations reported in this work aid in the understanding of infiltration into unsaturated, fractured, porous media. Conclusions regarding the calculated results are itemized as follows:

- Solutions obtained using the dual permeability model give a better representation of the flow in the fractures in the Fran Ridge experiment than do the equivalent continuum model results. Penetration distribution of the water through the fractures in the dual permeability model was greater than that calculated using the equivalent continuum model and was more consistent with the experimentally observed results. It is therefore recommended that the dual permeability model be carefully considered for use in performance assessment calculations pertaining to proposed-underground nuclear waste investigations.
- The observed infiltration rate was reasonably fitted, using as input the 640 experimentally observed fracture frequencies and 285 μm aperture for the fractures.
- The reduction of the calculated infiltration rate from 0.78 m^3 to 0.73 m^3 (less than 7%) when the core region was modeled with a homogeneous average of the experimentally observed fracture frequencies, implies that the fracture frequency on the subscale of 0.3 m by 0.3 m may not be critical for determining a good approximation of the infiltration at physical scales comparable to this experiment.
- Using the 285 μm fracture aperture, the total water influx for the equivalent continuum model was 2.2 times greater than that calculated using the dual permeability model. The matrix penetration was greater and the fracture penetration considerably less.

REFERENCES

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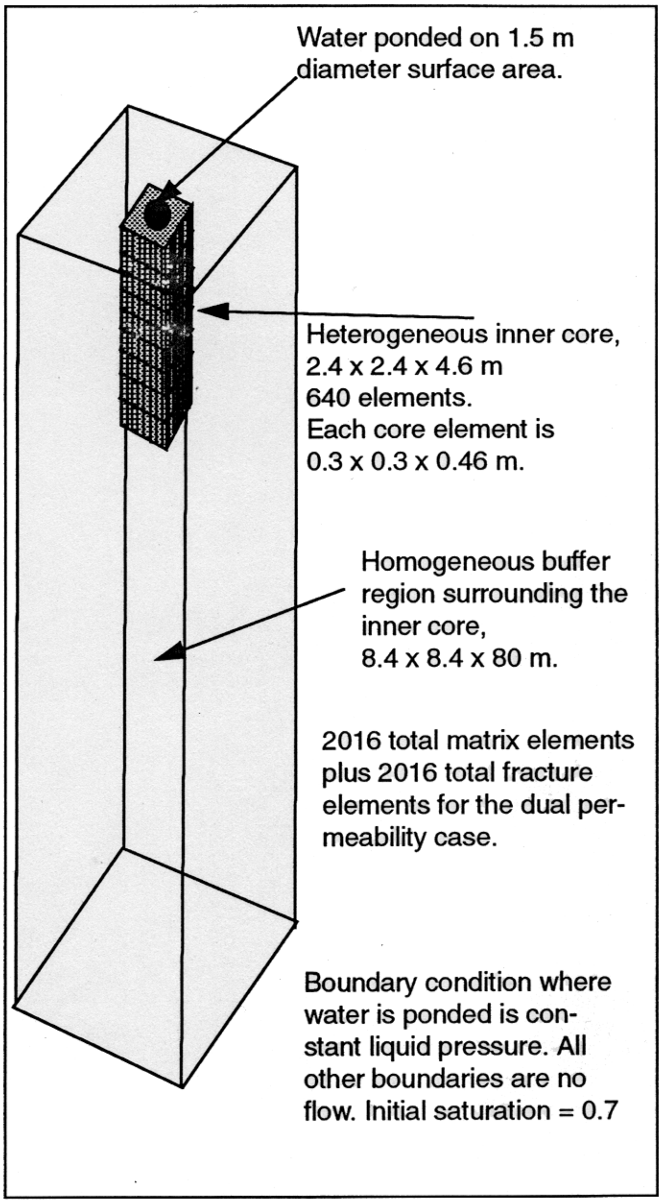

Figure 1. Problem geometry used to model the Fran Ridge infiltration experiment.

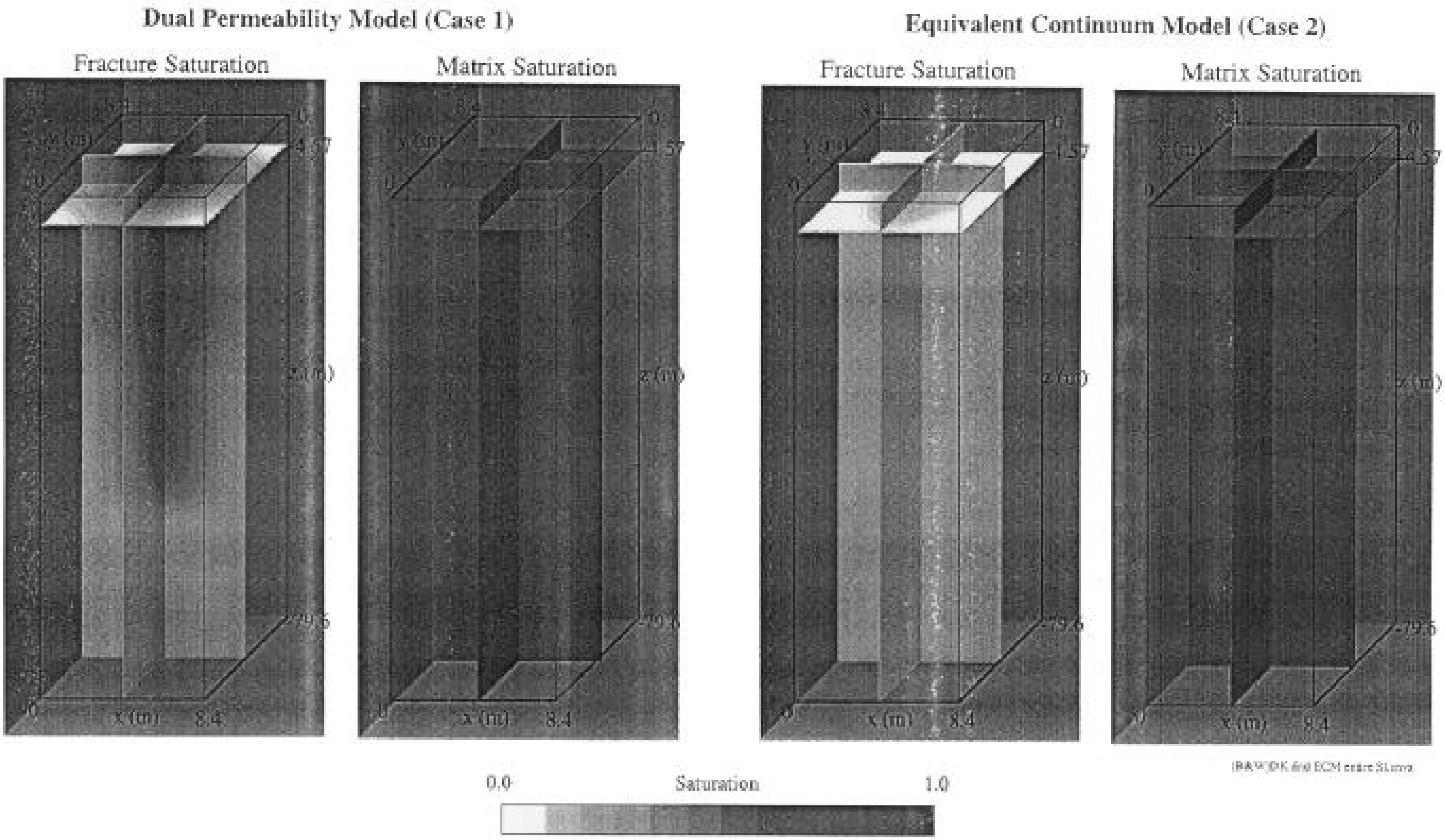

Figure 2. Planes of fracture and matrix saturations at 36 minutes resulting from the dual permeability model and the equivalent continuum model. The horizontal planes at z=-4.57 m correspond to the bottom of the heterogeneous core region (not to scale).