In Proceedings of "Int. High Level Radioactive Waste Management Conference" May, 1995, Las Vegas, Nevada, USA

EFFECTIVE MEDIA MODELS FOR UNSATURATED FRACTURED ROCK: A FIELD EXPERIMENT

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Introduction

A thick unsaturated rock mass at Yucca Mountain is currently under consideration as a potential repository site for disposal of high level radioactive waste. In accordance with standard industry and scientific practices, abstract numerical models will be used to evaluate the potential for radionuclide release through the groundwater system. In such models, the global problem is typically treated by representing the heterogeneous natural system as an ensemble of individually homogeneous elements. Each individual element is then assigned effective media properties which are assumed to be consistent with the heterogeneous natural domain that it represents. At this time, currently available conceptual models used to develop effective media properties are based primarily on simplistic considerations.

The work presented here is part of an integrated effort to develop effective media models at the intermediate block scale (approximately 8-125m^3) through a combination of physical observations, numerical simulations and theoretical considerations. The work encompasses:

- Experimentation (field, laboratory, and numerical) at scales sufficiently small to allow explicit investigation of small-scale flow processes.
- Measurement of matrix, fracture, and fracture network properties within an intermediate scale block.
- Synthesis of laboratory and field understanding into an intermediate scale conceptual model for use in numerical simulations.
- Use of numerical models such as FEHMN[1] or TOUGH2[2] to simulate effective properties for the synthesized intermediate scale block based on small-scale understanding and property measurement.

Here we describe a multi-purpose field experiment designed and conducted as part of this integrated effort. Specific goals of this experimental investigation were to: 1) obtain fracture network data from Topopah Spring Tuff for use in block scale simulations; 2) identify portions of the network conducting flow under three different boundary conditions; 3) visualize preferential flow paths and small-scale flow structures; 4) collect samples for subsequent hydraulic testing and use in block-scale simulations; and 5) demonstrate the ability of Electrical Resistance Tomography (ERT) to delineate fluid distribution within fractured rock.

Description of Work

A cooperative effort was established between Sandia National Laboratory and Lawrence Livermore National Laboratory (LLNL) to explore a natural fracture system at Fran Ridge. Ponded infiltration dye tracer tests were performed at three sites within the country rock surrounding LLNL's Large Block Test (LBT). After infiltration of the dye tracer (FD&C Blue #1), the host rock was excavated in a manner that allowed collection of pavement maps that included the distribution of dye tracer beneath the infiltration sites. Pavement maps were obtained at roughly 0.5 meter vertical intervals; exact elevation was determined by the excavation process.

Summary of Preliminary Results:

An illustrative example of a pavement map is shown as Figure 1. Between 7 and 12 horizontal pavement maps were obtained at each of the 3 sites; each map is limited to a 6 m^2 area located directly below the infiltration surface. It should be noted that the excavation technique leads to an inherent under sampling of low-angle fractures. Such data could be obtained from adjacent pit walls, sides of the LBT, and nearby USGS mapping pits. Integration of the aforementioned and other soft geologic information would further enhance the utility of this data set.

Pavement maps also contain information on dye tracer distributions, as shown by the dashed lines on Figure 1. At all three sites, dye tracer appeared to migrate outside of the mapped region implying significant lateral movement, probably along sub-horizontal features. Non-uniform dye stains were observed both on the pavements and in broken samples from the waste pile. However, the excavation method prohibited discrimination between gravity-driven fingering, heterogeneity-driven channeling, and surface chemistry as potential mechanisms for observed behavior.

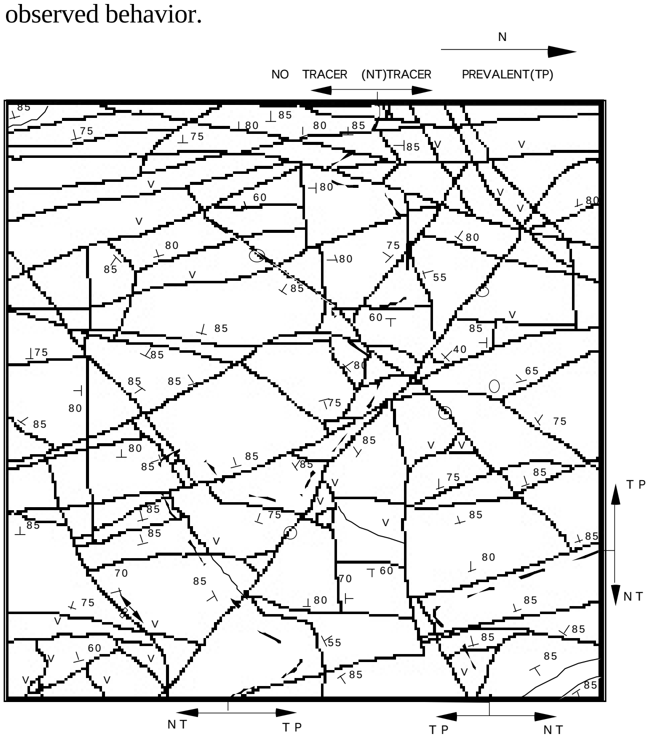

Figure 1: Example fracture map collected on 8/2/94 at approximately 4.5 m below the infiltration surface. Circles on the fracture trace indicate a significant amount of fracture filling, while the square box indicates a significant change in fracture dip along the plane.

ERT data were collected by LLNL at one of the test sites, complete analysis awaits evaluation of the pavement data. Samples of fractured rock were obtained for hydraulic properties testing during this next year (FY95). The destructive nature of the excavation method severely constrained sample collection within the dye tracer areas. Additional samples were collected from an intact region surrounding the LLNL LBT.

Conclusion

The field experiments presented in this summary are part of an integrated effort to build realistic effective media property models for unsaturated fractured rock relevant to the Yucca Mountain Project. Three ponded infiltration tracer tests were performed in the Topopah Springs unit at Fran Ridge. Data on fracture orientation, connection, dye tracer location, hydraulic properties, and small-scale flow processes were obtained during subsequent excavation of the test area. These data will provide both conceptual understanding and hard information to feed development of effective media properties through the vehicle of an intermediate scale block.

Acknowledgments

This work could not have occurred without the assistance of W. Lin and M. Owens at LLNL. Mapping assistance was provided by D. Engstrom and S. McKenna. ERT imagery was collected by B. Daily and A. Ramirez of LLNL. This work was supported by the U.S. Department of Energy, Office of Civilian Radioactive Waste Management, Yucca Mountain Site Characterization Project Office, under contract DE-AC04-94AL85000, WBS 1.2.5.4.6, WA-0152, and QAGR 1.2.5.4.6 Revision 0

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