



On the Validity of Darcy's Law for Stable High-Concentration Displacements in Granular Porous Media

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Abstract. Recently, it has been suggested that Darcy's Law might not be applicable for modelling miscible, density-dependent flow in porous media. To investigate this, three sets of careful laboratory column experiments were performed on coarse and medium sands, consisting of upward displacement of water by sodium chloride solutions with concentrations ranging from 5 to 200 g/l. Data on salt concentrations and water pressures were collected in horizontal transects along the flow direction. Salt concentration data were also collected in the influent and exit lines. The experimental data were analysed using a simplified approach based on Darcy's Law alone, applied with the assumption of a sharp interface. Darcy's Law was used to estimate porous medium permeability by fitting predictions to experimental data. Consistent estimates of permeability were obtained for each set of experiments. The results indicate that Darcy's Law adequately describes high concentration displacements through saturated coarse- and medium-grained porous media.

Key words: high density, medium sand, coarse sand, least-squares fitting, brine, soil column, miscible displacement, sodium chloride, numerical model.

1. Introduction

Miscible, density-dependent flows are commonplace in natural settings, for example, at coastlines or in estuaries. Also, geological salt deposits generate density variations in liquids percolating through them. Mining and industrial processes similarly give rise to such variations (Barbour and Yang, 1993; Fujijasu *et al.*, 1996). For example, in mining regions of Western Australia, ore processing makes use of saline groundwater, producing highly saline waste leachates. Thus, there

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is considerable interest in describing and modelling density-dependent flow and transport in porous media.

Downward displacements of fresh water by dense miscible solutions can give rise to instability. On the other hand, upward displacements of fresh water by brine are always stable. Theory and experiments on both stable and unstable displacements have been presented by various authors, including Slobod and Howlett (1964), Krupp and Elrick (1969), Hassanizadeh and Leijnse (1988), Hassanizadeh (1990), Hassanizadeh *et al.* (1990), Kempers (1991), Kempers and Haas (1994), Hassanizadeh and Leijnse (1995), Moser (1995), Anderson (1997) and Schotting *et al.* (1999). Although both unstable and stable flows are of great practical interest, in this paper we limit ourselves to presenting and analysing experimental data pertaining to the latter case.

There is a well established, 'classical' theory describing stable density-dependent flow. However, questions have been raised about its applicability in all circumstances. For example, it has been observed that dispersion at the solute front varies with density contrast (Kempers and Hass, 1994). On physical grounds it appears reasonable that low and high concentration displacements will exhibit different dispersion coefficients for stable, upward displacements. For upward high concentration displacements, density-driven lateral flow at the pore scale will tend to compress the zone of dispersion relative to a low-density tracer displacement. Hassanizadeh (1986) derived extended versions of Darcy's and Fick's Laws for situations in which high concentrations and high-concentration gradients are present. Hassanizadeh and Leijnse (1988) evaluated the potential significance of these extensions and proposed laboratory experiments for investigating them. Such experiments were carried out by Hassanizadeh *et al.* (1990) and analysed by Hassanizadeh (1990). He found that neither the classical nor the extended versions of Fick's Law could accurately reflect the transport mechanisms occurring in brine displacement experiments. Instead, he developed a non-linear dispersion theory for high concentration displacements, which was subsequently tested and partially validated by Hassanizadeh and Leijnse (1995). More extensive experiments, including variations of flow velocity and resident water salt concentration, were carried out by Moser (1995). These experiments were fully analysed by Schotting *et al.* (1999). The most important finding in the work of Schotting *et al.* (1999) is the experimental confirmation of validity of the extended Fick's Law, as proposed by Hassanizadeh and Leijnse (1995). The question of the validity of Darcy's Law, however, remains unanswered. The pressure data from the experiments of Moser (1995) did not allow for a careful analysis aimed at addressing the applicability of Darcy's Law. As a consequence, Schotting *et al.* (1999) focused on the nonlinear extension of Fick's Law, under the assumption that the 'classical' Darcy's Law was valid.

Thus far, only a limited amount of experimental data has been presented on the movement of highly saline solutions through porous media. Recently, a large set of careful experiments were carried out and described in detail by Anderson (1997).

In particular, she performed experiments aimed at investigating the validity of Darcy's Law for cases of high-concentration displacements. In this paper, we present and analyse those data sets and, thereby, check the applicability of Darcy's Law for describing flow in granular porous media.

2. Experimental Procedure

One-dimensional laboratory column experiments were conducted to investigate brine transport through two types of saturated sand. The column experiments consisted of stable upward displacements (i.e. fresh water displaced by salt water). Two types of boundary conditions were used, either a constant displacement head (i.e. pressure), or a constant flow rate. The influent consisted of sodium chloride solutions with concentrations ranging from 5 to 200 g/l. The concentration, density and viscosity of the test solutions are presented in Table I, where the displacement solution properties, taken from Weast (1977), are shown. The laboratory apparatus included an acrylic column with a detachable base and a piston top cap. The internal diameter of the column was 80 mm, and the final packed soil length was approximately 435 mm. The column was instrumented with pressure transducers and soil conductivity probes (Watson and Culigan, 1999), allowing the pore fluid pressure and concentration to be measured and logged at various locations along the length of the column. A diagram of the column apparatus is given in Figure 1.

Instrumentation fixtures were located at six levels along the length of the column, labelled L1–L6 in Figure 1. Pore pressure transducers were located at levels L1–L5 to measure the pore fluid pressure at approximately 100-mm intervals. The pore pressure measurements were taken at a location approximately 20 mm from the column wall to avoid edge effects.

Soil electrical conductivity probes, for measuring pore fluid salt concentration, were located at levels L1–L5. A soil conductivity probe was also located at the top of the soil column (level L6) to measure the exiting fluid concentration. Also, a tube conductivity probe was located in the effluent fluid line to measure the

Table I. Test solution properties at 20°C

| Concentration (g/l) | Density (kg/m ³) | Absolute Viscosity (Ns/m ²) |
|------------------------|---------------------------------|--|
| 0.0 | 998.2 | 1.00×10^{-3} |
| 5.0 | 1001.8 | 1.01×10^{-3} |
| 50.0 | 1032.9 | 1.08×10^{-3} |
| 100.0 | 1066.1 | 1.18×10^{-3} |
| 150.0 | 1098.2 | 1.30×10^{-3} |
| 200.0 | 1129.6 | 1.45×10^{-3} |

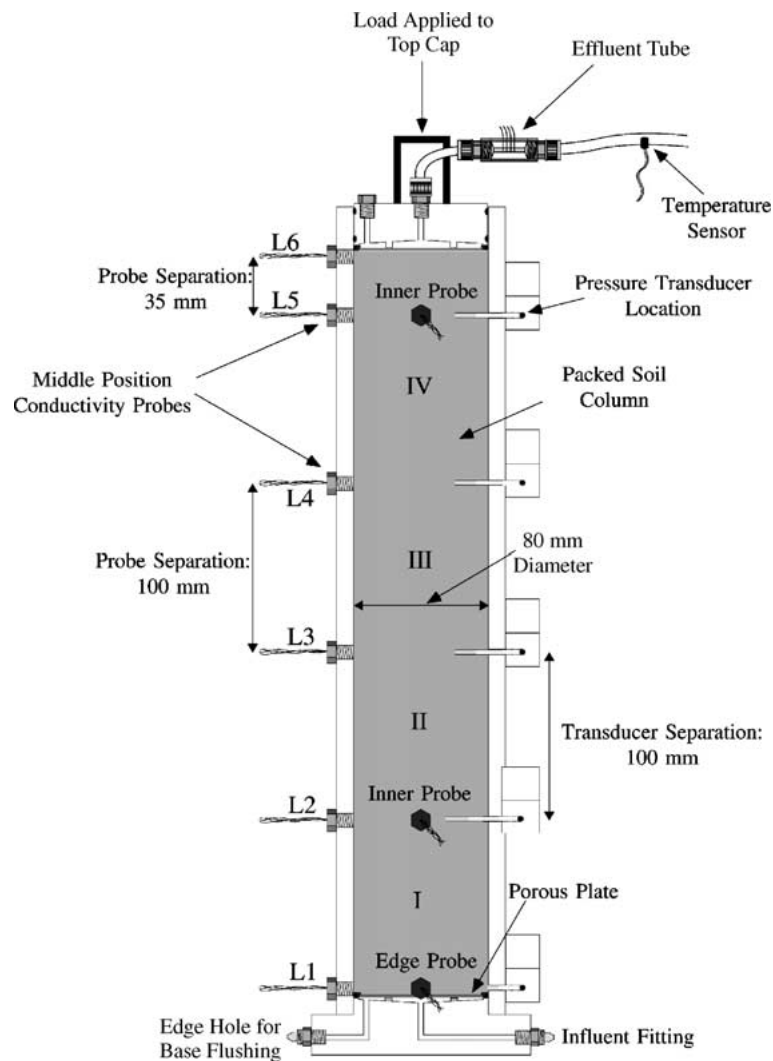


Figure 1. Schematic diagram of the laboratory column apparatus.

effluent concentration. Three conductivity probes were located at levels L2 and L5 to measure the pore fluid concentration at the edge, inner and middle regions of the column (Figure 2). The purpose of measuring pressure and concentration transverse to the mean flow direction was to assess the presence of nonuniform flow within the column. For the one-dimensional analysis reported below, it is important for flow nonuniformity to be minimal, so as not to affect the results of the analysis. However, in practice, it is not possible to avoid it, particularly for the low concentration displacements. The columns used in the experiments had an entrance baffle system that minimised nonuniform flow in most cases (Anderson, 1997), but not in the low concentration displacements for the MS test series (Table II).

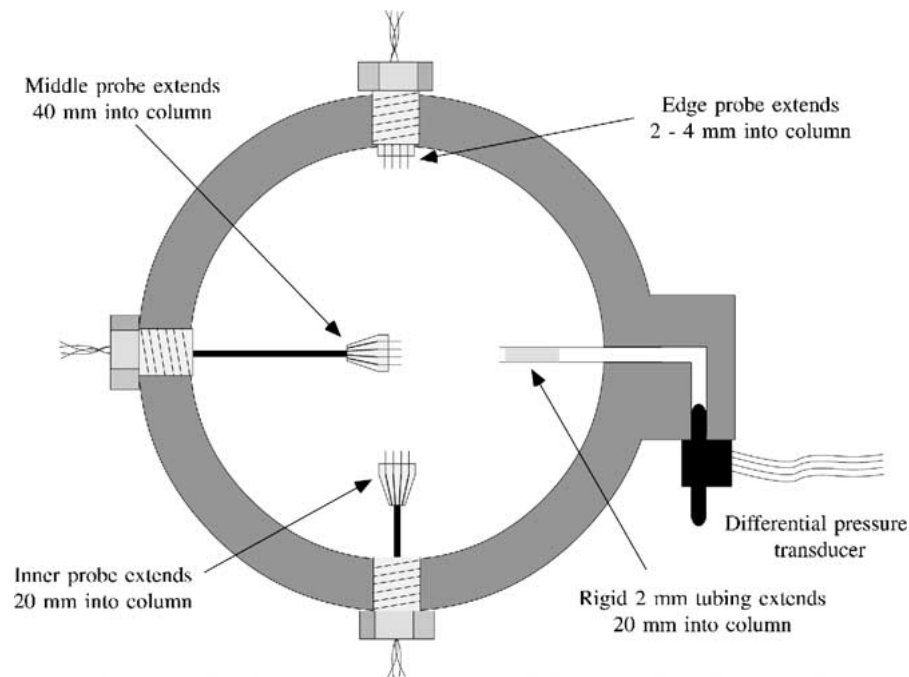


Figure 2. Cross-section at levels L2 and L5.

Table II. Outline of the stable upward displacement experiments.

| Sand type | Median grain size (mm) | Number of displacements | Test names | Experiment type |
|-----------|------------------------|-------------------------|------------|-----------------|
| Coarse | 0.73 | 9 | CS1-5u – | Constant |
| | | | CS3-200u | Head |
| Coarse | 0.73 | 7 | CS5-5u – | Constant |
| | | | CS6-200u | Flux |
| Medium | 0.27 | 6 | MS1-5u – | Constant |
| | | | MS2-200u | Flux |

Coarse and medium sands, with average grain sizes of 0.73 mm and 0.27 mm, respectively (Table II) were used. The column was packed under wet conditions with vibration to obtain a maximum packed soil density. For the constant head displacements, the column apparatus was set up with the overflow level of the displacing solution fixed to a desired height. For the constant flux displacements, the displacing solution was supplied to the column apparatus from an influent solution vessel that was manually raised or lowered during each displacement to maintain an approximately constant flow rate through the soil column. Using this technique, the flux values varied by less than 8% of the ‘average’ flux through the column

Table III. Summary of the coarse sand constant head experiments

| Test name | Influent concentration (g/l) | Minimum flux (mm/min) | Maximum flux (mm/min) |
|-----------|------------------------------|-----------------------|-----------------------|
| CS1-5u | 5 | 14.3 | 14.3 |
| CS1-50u | 50 | 12.9 | 14.1 |
| CS1-200u | 200 | 11.4 | 16.4 |
| CS2-5u | 5 | 13.8 | 13.8 |
| CS2-50u | 50 | 13.0 | 14.4 |
| CS2-200u | 200 | 10.7 | 15.4 |
| CS3-5u | 5 | 13.3 | 13.3 |
| CS3-50u | 50 | 12.9 | 14.0 |
| CS3-200u | 200 | 12.0 | 16.3 |

during any single displacement. To check for variations in flow rate, the effluent solution was collected in a vessel, the weight of which was logged throughout each displacement. As stated above, the concentration of the effluent was measured by a tube conductivity probe located at the end of the effluent line, thus the density of the solution entering the effluent vessel was known. The effluent density and cumulative mass measurements were then used to determine the effluent flow rate.

Table II contains a summary of the experimental series. Details of all the constant head displacement experiments (9 in all) are given in Table III, while those for the constant flux experiments (13 in all) are listed in Table IV. Note that the same packed column was used for each test series. So, CS1–CS3 were conducted in the same packed column, CS5–CS6 were in another packed column, as were MS1–MS2.

The data obtained for each experiment consisted of conductivity measurements from the 12 soil probes and effluent tube probes, pressure measurements and the cumulative effluent mass. The data were then converted into solute breakthrough curves, pore pressure curves and an effluent flux curve.

3. Results and Analysis

3.1. CONCENTRATION DATA

Because the analysis presented here is focused entirely on Darcy's Law, the concentration data (in the form of breakthrough curves, BTCs) are not subjected to close examination. A detailed analysis of the concentration data is lengthy, as it is based on full numerical solutions of the governing coupled flow and transport equations (Voss, 1984; Watson and Barry, 2001) and is available elsewhere (Anderson *et al.*, 1996; Anderson, 1997; Anderson and Barry, 1997). We do, however, use the BTCs

Table IV. Summary of the coarse and medium sand constant flux experiments

| Test name | Influent concentration (g/l) | Average flux (mm/min) |
|-----------|------------------------------|-----------------------|
| CS5-5u | 5 | 15.6 |
| CS5-200u | 200 | 15.5 |
| CS6-5u | 5 | 5.98 |
| CS6-50u | 50 | 6.14 |
| CS6-100u | 100 | 6.23 |
| CS6-150u | 150 | 6.14 |
| CS6-200u | 200 | 6.21 |
| MS1-5u | 5 | 11.8 |
| MS1-200u | 200 | 11.7 |
| MS2-5u | 5 | 8.05 |
| MS2-50u | 50 | 7.80 |
| MS2-100u | 100 | 8.06 |
| MS2-200u | 200 | 8.06 |

in three ways. First, the time corresponding to the relative concentration 0.5 can be used to estimate the column porosity for the constant flux experiments (Barry and Parker, 1987). For the constant head displacements, this time can be used to check the Darcy's Law analysis (§ 3.2). Second, since density changes with concentration, the concentration data are needed to compute the effluent volume flux from the measured effluent mass. Third, the concentration data, particularly at levels L2 and L5, were used to check the extent of nonuniform flow. Nonuniform flow was negligible for the displacements in coarse sand. Slight non-uniform flow was apparent for the low concentration displacements in the medium sand. However, for low concentration displacements, nonuniform flow will not have an appreciable effect on the analysis of the pressure curves and so do not affect our investigation of the validity of Darcy's Law. The results presented and analysed below are therefore considered to be unaffected by nonuniform flow.

Typical BTCs are shown in Figures 3 and 4. These figures show the BTCs to have the expected behaviour in that they are reasonably symmetric and exhibit increasing spreading with increased residence time in the column. Other experiments as listed in Tables III and IV give similar results, and so their BTCs are not presented.

3.2. PRESSURE DATA

We present, in Figures 5(a)–(c) and 6(a)–(c), typical measured pressure traces at various locations within the soil columns during the course of the high-

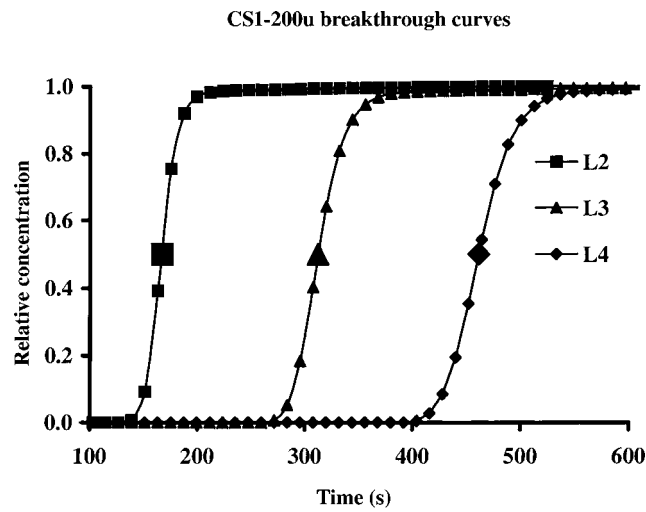


Figure 3. Experiment CS1-200u: breakthrough curves at locations L2, L3 and L4. Enlarged symbols show the location where relative concentration is 0.5.

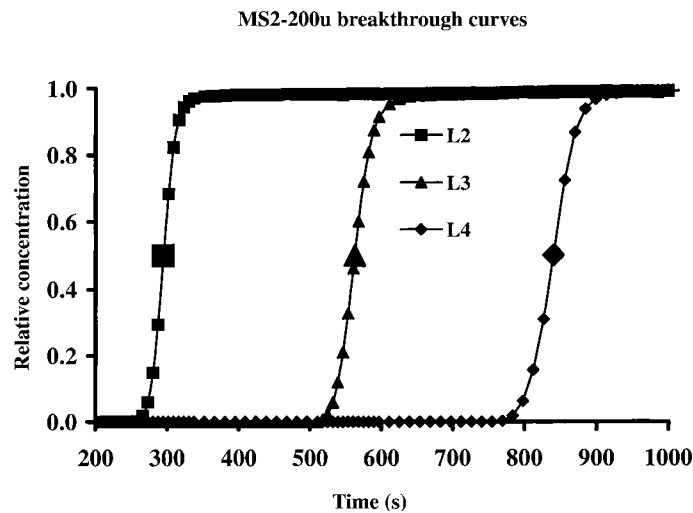


Figure 4. Experiment MS2-200u: breakthrough curves at locations L2, L3 and L4. Enlarged symbols show the location where relative concentration is 0.5.

concentration displacement experiments. The vertical lines showing the concentration interface correspond to the 0.5 relative concentration as shown in Figures 3 and 4. Very clear changes in gradient are apparent at these locations. Observe that two types of experimental boundary conditions are presented, constant head – Figure 5 – and constant flux – Figure 6.

For all the experiments, the shape of the pressure curves varied depending on the concentration of the displacing solution and the boundary conditions being imposed on the soil column. For the low concentration displacements, the pressure

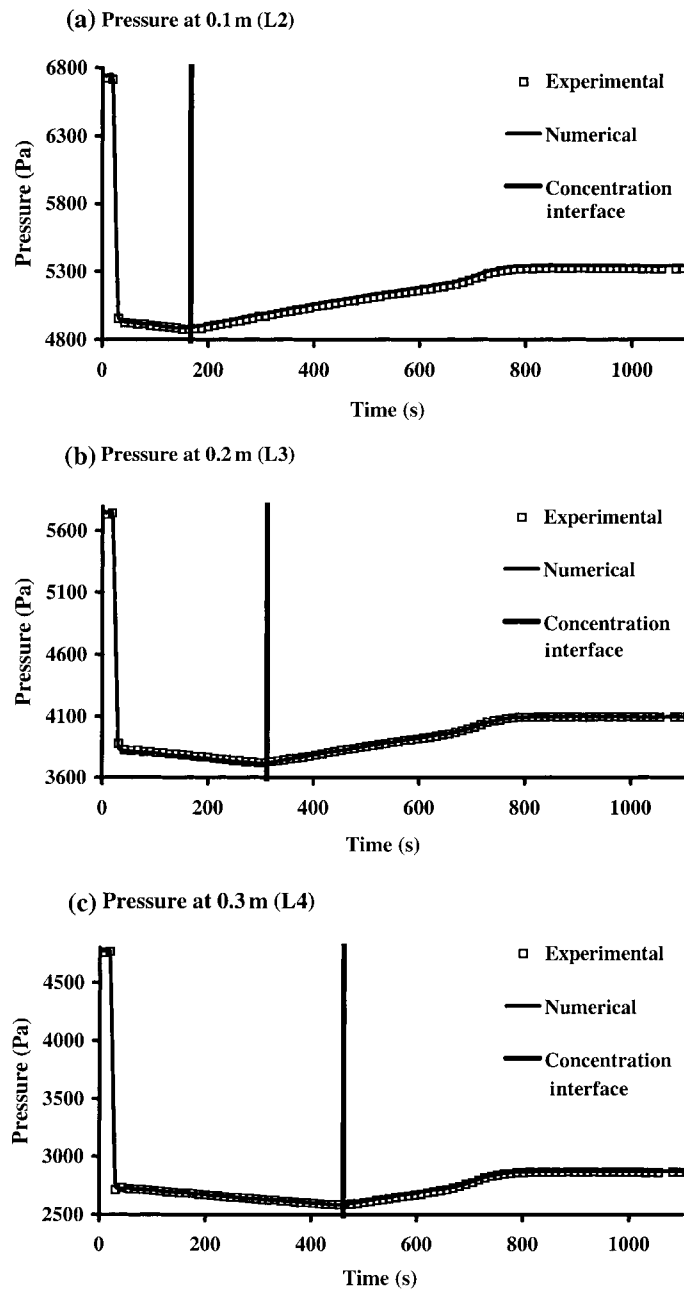


Figure 5. Experiment CS1-200u: results of fitting measured pressure data within the column and effluent volume. Measured and fitted pressures at (a) L2, (b) L3 and (c) L4.

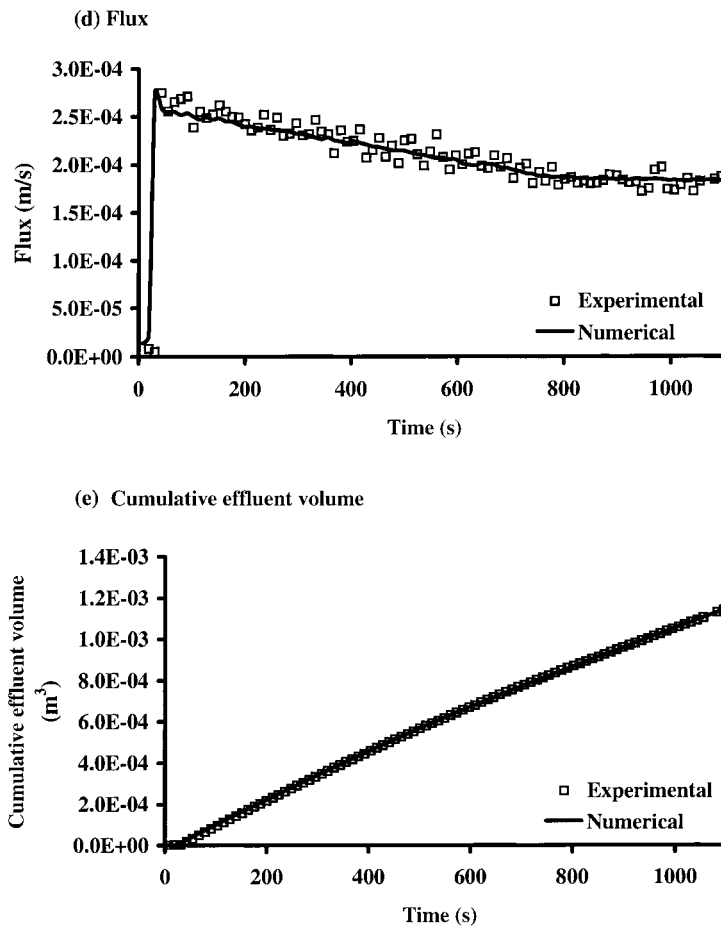


Figure 5. (continued) (d) effluent flux and (e) total effluent volume.

curves were all approximately horizontal under constant pressure boundary conditions, which gave rise to a constant flux through the column. Put another way, horizontal pressure traces will always occur for steady flow of a homogeneous liquid through the column (e.g. $t > 800$ s in Figure 5(c)).

For the higher concentration displacements, the shape of the pressure curves varied depending on whether constant head or constant flux boundary conditions were imposed. The concentration of the displacing solution also affected the magnitude of the pressure changes that were measured during each displacement. In general, when a high concentration stable displacement is conducted within a water-saturated soil column, a greater driving force is required to move the more viscous fluid through the soil and to displace the denser fluid upwards through it.

Under constant pressure (or head) boundary conditions, the pressure at each transducer location reduced as the solute front approached (e.g. between $t = 30$ s and $t = 440$ s in Figure 5(c)), and increased once the solute front had passed

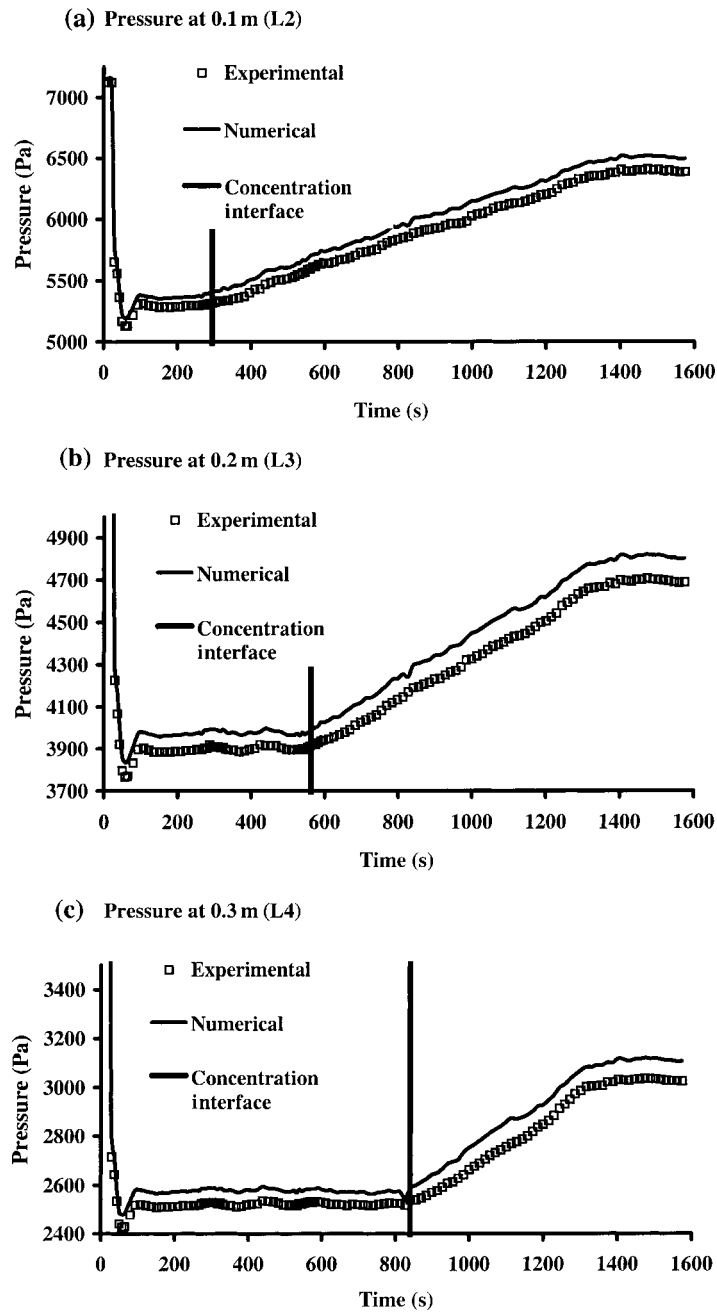


Figure 6. Experiment MS2-200u: results of fitting measured pressure data within the column and effluent volume. Measured and fitted pressures at (a) L2, (b) L3 and (c) L4.

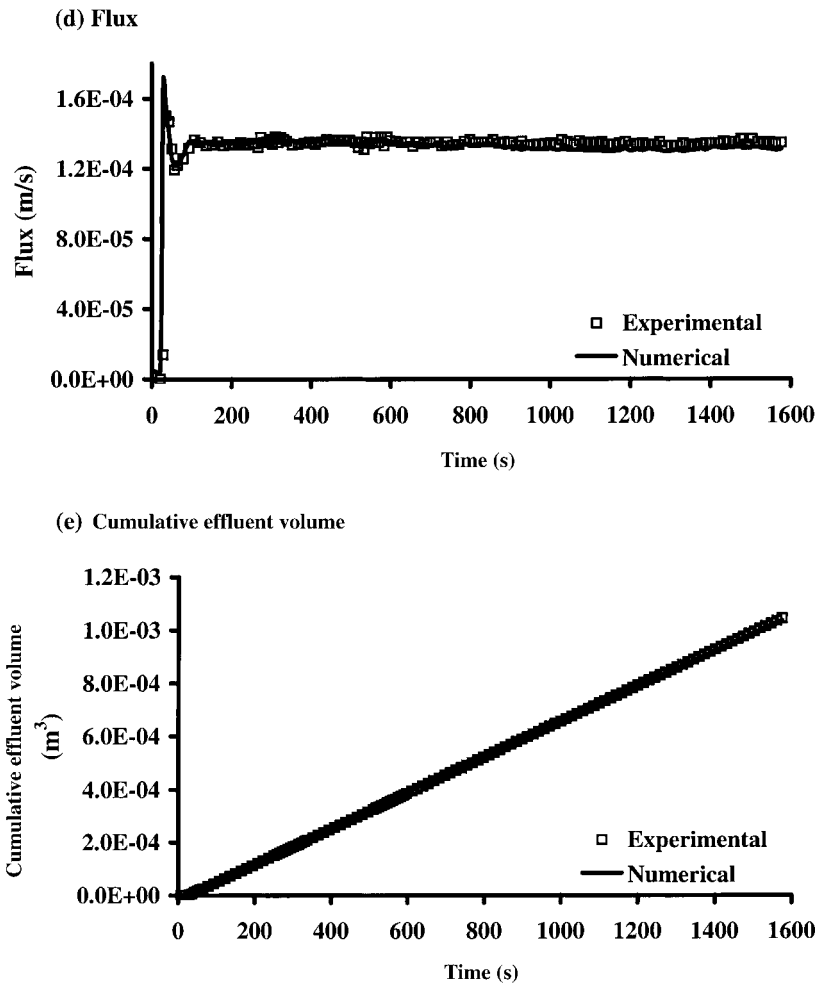


Figure 6. (continued) (d) effluent flux and (e) total effluent volume.

(e.g. between $t = 450$ s and $t = 750$ s in Figure 5(c)). The pressure reduced as the front approached because there was greater head loss between the base of the column, which remained at a constant pressure, and the location of the pressure transducer as the more viscous and more dense influent solution displaced the water within the column.

Once the solute front had passed the pressure transducer, it was not affected by the location of the solute front, but rather was affected by the flux through the column. As the pressure at the boundaries did not change, the flux through the column reduced, which resulted in an increasing pressure at the location of the pressure transducers once the solute front had passed.

The pressure at the boundaries was not measured during the constant head experiments, however a constant influent and effluent head was maintained by

Table V. Range of pressures measured at levels L1 and L5 for the constant head experiments

| Test name | Pressure at Level L1 (kPa) | Pressure at Level L5 (kPa) |
|-----------|----------------------------|----------------------------|
| CS1-5u | 5.87–5.88 | 1.52–1.54 |
| CS1-50u | 5.89–6.00 | 1.49–1.55 |
| CS1-200u | 6.03–6.55 | 1.46–1.64 |
| CS2-5u | 5.85–5.86 | 1.51–1.53 |
| CS2-50u | 5.87–5.98 | 1.47–1.52 |
| CS2-200u | 5.96–6.44 | 1.39–1.57 |
| CS3-5u | 5.84–5.86 | 1.51–1.55 |
| CS3-50u | 5.91–6.01 | 1.51–1.60 |
| CS3-200u | 6.12–6.60 | 1.51–1.73 |

keeping the influent supply vessel and the effluent line at fixed elevations. The pressure was measured at levels L1 and L5 within the column (Table V). The variation in measured pressure at these locations shows the effect of density change in the displacing solution, for example, the higher measured pressures correspond to the final pressures shown in Figures (a)–(c).

Under constant effluent flux and constant exit pressure boundary conditions, the influent pressure at the base of the column was changed to maintain a constant flux. Under these conditions, the pressure at each transducer within the column remained constant as the solute front approached (e.g. between $t = 150$ s and $t = 800$ s in Figure 6(c)), and increased once the solute front had passed (e.g. between $t = 900$ s and $t = 1300$ s in Figure 6(c)). The pressure remained constant because (i) the greater head loss between the base of the column and the location of the pressure transducer was balanced by increasing the influent pressure and (ii) the zone between the pressure transducer and the column exit was water-saturated, and so the head loss through this zone remained constant.

Once the solute front had passed the pressure transducer, the pressure was not affected by the location of the solute front, but rather increased with the increasing pressure at the base of the column. Conversely, if the pressure at the base of the column had remained constant and the exit pressure had been varied to maintain a constant effluent flux, the pressure at each transducer location would have reduced as the front approached, and would have remained constant once the front had passed.

The foregoing discussion is based on changes in pressure at a given location. An alternative view, that of spatial changes in head at two different times (locations) is shown in Figure 7.

The pressures measured at level L1 and level L5 within the column during the constant flux experiments are presented in Table VI. Again, the low density

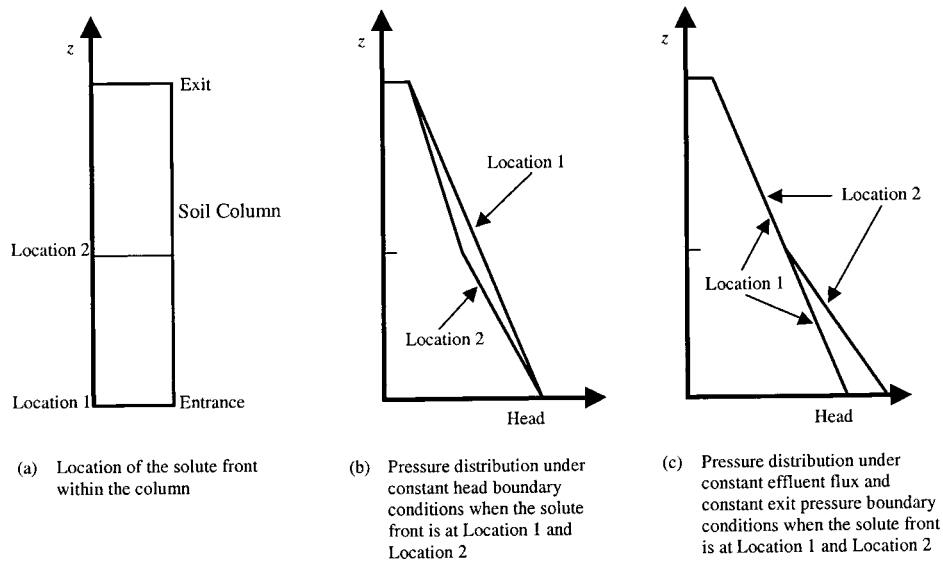


Figure 7. Schematic representation of changes in pressure distribution as a sharp solute front moves through a soil column. (a) Front locations at entrance and half way through the column. (b) Pressure changes at each location for fixed pressure boundary conditions. (c) Pressure changes at each location for constant flux boundary conditions.

Table VI. Range of pressures measured at levels L1 and L5 for the constant flux experiments

| Test name | Pressure at level L1 (kPa) | Pressure at level L5 (kPa) |
|-----------|----------------------------|----------------------------|
| CS5-5u | 6.12–6.21 | 1.65–1.71 |
| CS5-200u | 6.14–7.29 | 1.62–2.03 |
| CS6-5u | 5.27–5.29 | 1.11–1.13 |
| CS6-50u | 5.37–5.61 | 1.24–1.32 |
| CS6-100u | 5.39–5.82 | 1.24–1.38 |
| CS6-150u | 5.40–6.04 | 1.24–1.44 |
| CS6-200u | 5.35–6.09 | 1.13–1.32 |
| MS1-5u | 7.75–7.87 | 1.52–1.57 |
| MS1-200u | 8.01–9.54 | 1.48–1.82 |
| MS2-5u | 6.75–6.80 | 1.23–1.25 |
| MS2-50u | 6.62–6.87 | 1.16–1.20 |
| MS2-100u | 6.69–7.29 | 1.18–1.28 |
| MS6-200u | 6.82–8.15 | 1.17–1.44 |

displacements show very little change in measured pressures, whereas for high density displacements marked changes relative to the corresponding cases in Table V are evident.

Because each set of experiments was carried out using the same packed column (Table II), the porosity for each set of experiments was fixed to be the average column porosity measured at the end of each test series (Anderson, 1997). In addition, porosity estimates could be obtained directly from high concentration displacements, as the inflections in the pressure curves mark the transition zone between the saline influent solution and the fresh water initially present within the column. Thus, by analysing the high-concentration experiments, estimates of the porosity were obtained. These were found to agree reasonably with the measured porosity values, and are used below.

A simplified analysis of the pressure data for each experiment, based on Darcy's Law alone, was carried out to obtain estimates of the average intrinsic permeability of the soil column from the pressure measurements at levels L1–L5. The analysis was carried out by applying Darcy's Law at regular time increments to the zone of soil within the column that was permeated with resident fresh water and to the zone of soil that was permeated with the saline influent solution. This resulted in two equations that were solved for the pressure at the interface between the saline influent solution and resident water. For the simplified analysis, this interface was assumed to be an abrupt front. The boundary conditions for the analysis were the measured pressures at the base of the column, level L1, and at level L5 within the column.

An iterative approach was used to solve the two equations at each time increment for the pressure at the interface. At each time increment, the interface was initially moved through a distance based on the calculated flux from the previous time step. The pressure at the interface was then calculated. The flux through the column was calculated by applying Darcy's Law to the zone of soil that was permeated with the saline influent solution. The position of the interface was then adjusted based on the recalculated flux, and the pressure at the interface was recalculated. This set of calculations was carried out until satisfactory convergence of the pressure at the interface was obtained for each time increment. Subsequently, the pressures at levels L2, L3 and L4 within the column were calculated for each time increment using Darcy's Law.

To obtain estimates of the average intrinsic permeability, the calculated pressure curves at levels L2, L3 and L4 and the calculated cumulative effluent volume curve (based on the calculated flux) were fitted (using least-squares fitting) to the measured pressure and cumulative effluent volume curves for each experiment. These are also presented in Figures 5 and 6.

4. Discussion

The permeability estimates from the simplified analysis are presented in Table VII. Recall that the experiments were carried out on three packed columns, so that if

Table VII. Fitted permeabilities and measured porosities for each experiment

| Test name | Porosity (fixed) | Fitted permeability (mm ²) |
|-----------|---------------------|---|
| CS1-5u | 0.35 | 2.08×10^{-10} |
| CS1-50u | 0.35 | 2.05×10^{-10} |
| CS1-200u | 0.35 | 2.10×10^{-10} |
| CS2-5u | 0.35 | 2.05×10^{-10} |
| CS2-50u | 0.35 | 2.05×10^{-10} |
| CS2-200u | 0.35 | 2.12×10^{-10} |
| CS3-5u | 0.35 | 2.05×10^{-10} |
| CS3-50u | 0.35 | 2.07×10^{-10} |
| CS3-200u | 0.35 | 2.14×10^{-10} |
| CS5-5u | 0.34 | 1.72×10^{-10} |
| CS5-200u | 0.34 | 1.78×10^{-10} |
| CS6-5u | 0.34 | 1.55×10^{-10} |
| CS6-50u | 0.34 | 1.67×10^{-10} |
| CS6-100u | 0.34 | 1.69×10^{-10} |
| CS6-150u | 0.34 | 1.63×10^{-10} |
| CS6-200u | 0.34 | 1.60×10^{-10} |
| MS1-5u | 0.37 | 3.29×10^{-11} |
| MS1-200u | 0.37 | 3.26×10^{-11} |
| MS2-5u | 0.37 | 3.21×10^{-11} |
| MS2-50u | 0.37 | 3.24×10^{-11} |
| MS2-100u | 0.37 | 3.26×10^{-11} |
| MS2-200u | 0.37 | 3.23×10^{-11} |

Darcy's Law was valid we would expect that the fitted permeabilities for each packed column would be identical except for experimental errors. Thus, for each packed column, we took the measured porosity value and fitted the permeability, as shown in Table VII. The consistency in the permeability estimates is remarkably good, and thereby supports the case that Darcy's Law is applicable to high concentration displacements.

It is worth noting that, as mentioned in Section 2, nonuniform flow is always present to some extent in all column experiments, including those reported here. We reiterate that, with respect to the pressure analysis, non-uniform flow is of little concern at the lower concentrations, as it has negligible effect on the pressure results so long as the flow is essentially one-dimensional. As non-uniform flow reduces with increasing concentration due to density-driven stabilisation of the front, it is not considered an issue in the results reported here.

The quality of the fits obtained varied with the experiments. However, overall the fits obtained were extremely good in that all key features of the measured data were reproduced by the predictions. Generally better fits were obtained for the coarse sand experiments, with slightly worse results for the medium sand experiments. Typical results for the coarse sand experiments are shown in Figure 5. These fits are excellent. As mentioned, the vertical lines shown in the figure are the times (obtained from Figure 3) where the relative concentration is 0.5. As the concentration front passes a given location, there is a distinct change in the slope of the pressure trace. This agreement indicates that the porosity and permeability values used to compute the pressure curves are reliable.

To compare with these, we present also what is by far the worse fit of Darcy's Law for the experimental series reported here. These results, obtained for the medium sand, are given in Figure 6. Again, there is a change in the pressure gradient, indicating the passage of the concentration front.

Figure 6 shows measured pressure traces to be offset from the predicted traces. On the other hand, the flux and cumulative effluent predictions in Figure 6(d) and (e) are very close. This is an artifact of the fitting procedure: we weighted the effluent fits strongly in the procedure to estimate the permeability as it was suspected that the locations of the *in situ* probes were not known to great accuracy, whereas the effluent measurements were not subject to location errors. Even so, the pressure traces in Figure 6 show a consistent error, which might indicate a bias in the analysis. Without a more detailed analysis it is not possible to clarify this point. However, we suggest that the agreement between the predicted and measured pressures in this figure is still very good. A more complete analysis (Anderson, 1997) considers both the pressure and concentration data and finds, as we do here, that Darcy's Law is satisfactory for modelling density-dependent flow.

5. Conclusions

A series of careful experiments on upward (stable) displacements of fresh water by denser (salt water) solutions in two types of porous medium was presented. These experiments were designed to provide data sets for testing density-dependent flow and transport theories. In this paper, the applicability of Darcy's Law was tested using a simplified approach that treated the interface between the (displaced) fresh and (displacing) salty solutions as being sharp.

The analysis, while simple, showed that the measured *in situ* pressures were predicted well for the coarse and medium sand experiments, based on consistent fitted values of permeability and measured porosity.

Overall, the results of this analysis suggest that Darcy's Law is applicable for modelling brine displacements in coarse and medium sands.

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