TUDelft

Deltares
Enabling Delta Life

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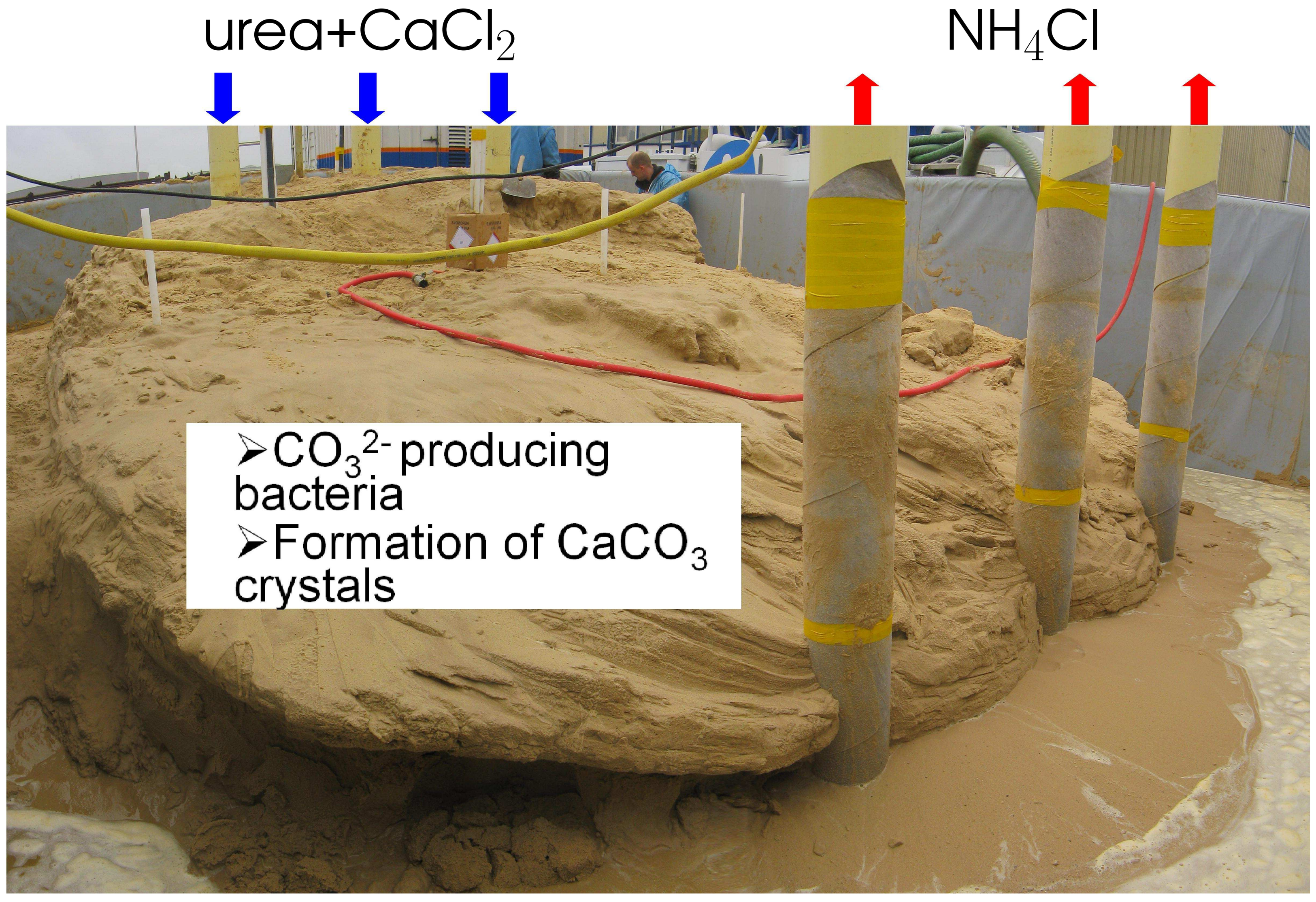
Modelling Biogrout:

a new ground improvement method

Introduction

The Biogrout process is illustrated by the following picture:



The crystals form bridges between the sand grains, thereby causing **strength**. As a result of the production of $CaCO_3$, the porosity and permeability decrease.

Mathematical Model

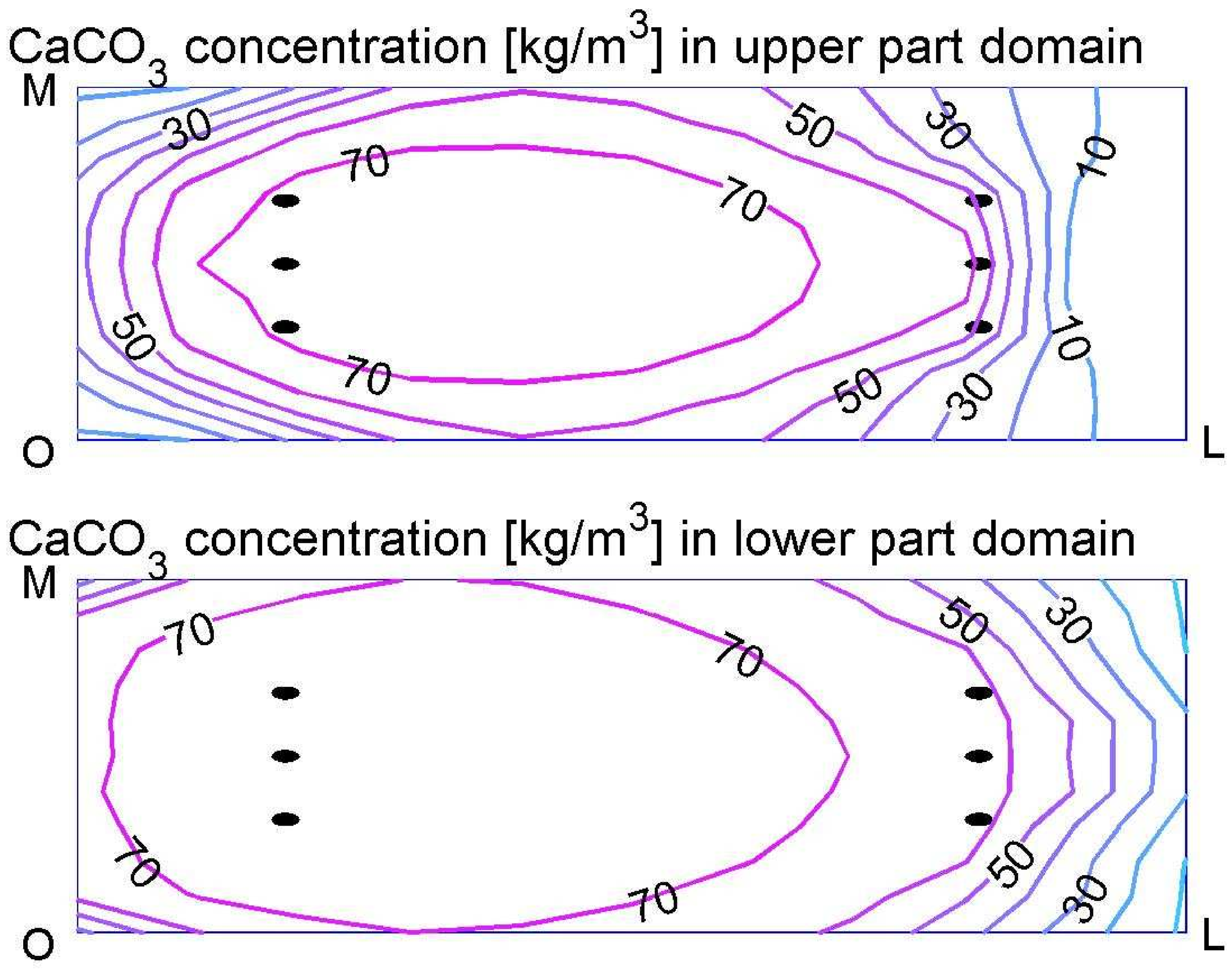
The model contains the following relevant parameters for the Biogrout process:

- **Bacterial activity** (currently taken constant);
- **Pressure and flow** (Darcy's Law);
- **Concentrations of the various species** (advection-dispersion-reaction-equations);
- **Density** (direct dependence on concentrations);
- **Porosity and permeability** (direct dependence on $CaCO_3$ content).

This system of coupled, non-linear equations is solved with the Finite Element Method. At each time step, new matrices are built. The CPU-time is partly spent on building matrices and partly on solving the matrix-vector equations, using a direct solver.

Numerical Results

The next figure displays some numerical results of the full scale experiment, shown left. The difference between the upper and lower part of the domain is caused by density driven flow.



The table shows the CPU time per time step, subdivided in the building and solving part for seven meshes. Further, the relative error in an arbitrarily chosen point compared to the finest mesh is shown.

#el.	CPU time (s)			%	rel.
(±)	time step	building	solving	solving	error
2500	0.344	0.242	0.102	30%	24%
5000	0.715	0.459	0.255	36%	15%
10000	1.58	0.921	0.661	42%	10%
20000	4.28	1.88	2.39	56%	6.3%
40000	13.9	3.80	10.1	73%	3.5%
80000	46.8	8.23	38.6	82%	1.1%
160000	182	17.0	165	91%	(0%)

Conclusions

- Numerical results confirm our expectations;
- Convergence is $O(\Delta t + \Delta x^2)$;
- For a large number of elements, an efficient solver should be used, e.g. an iterative solver.

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