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Optimized shape design of gravel drains in liquefaction countermeasures

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Liquefaction countermeasures are roughly categorized into two methods, one is the gravel drain method, the other is the sand compaction pile method. These methods mainly aim the reduction of excess pore water pressure in underground during earthquakes. We focus on the gravel drain method in terms of optimal shape design of the gravel drains having a superior drainage performance.

To detect such optimized drain shape, we convert the practical problem into
a mathematical programming problem involving the partial differential equations concerning seepage flow.
Then an efficient mathematical programming technique in conjunction with the finite element method (FEM) is employed.

The problem solving process consists of three operations:
(1) Solve the partial differential equation for seepage flow by the FEM.
(2) Perform the sensitivity analysis based on the adjoint variable method.
(3) Solve the mathematical programming problem to update the design variable.
These operations are continued until the convergence with respect to the objective function value and robustly detect the optimized drain shape within a reasonable CPU time.

The tendencies and remarks of the obtained optimal drain shapes are clearly found that those optimized shapes are similar to the roots of plants in the underground and dramatically reduce the mean of hydraulic head as compared with those of the normal gravel drains. Moreover, it is also found that the fractal dimension of the optimal drain shape is measured as D=2.3, which corresponds to those measured in blood capillary systems inside the living creatures.

Keywords: liquefaction, gravel drain method, finite element method, optimization