Passive Site Remediation for Mitigation of Liquefaction Risk

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ABSTRACT

Passive site remediation is a new concept proposed for non-disruptive mitigation of liquefaction risk at developed sites susceptible to liquefaction. It is based on the concept of slow injection of stabilizing materials at the edge of a site and delivery of the stabilizer to the target location using the natural groundwater flow. The purpose of this research was to establish the feasibility of passive site remediation through identification of stabilizing materials, a study of how to design or adapt groundwater flow patterns to deliver the stabilizers to the right place at the right time, and an evaluation of potential time requirements and costs.

Stabilizer candidates need to have long, controllable gel times and low viscosities so they can flow into a liquefiable formation slowly over a long period of time. Colloidal silica is a potential stabilizer for passive site remediation because at low concentrations it has a low viscosity and a wide range of controllable gel times of up to about 100 days.

Loose Monterey No. 0/30 sand samples (D_r = 22%) treated with colloidal silica grout were tested under cyclic triaxial loading to investigate the influence of colloidal silica grout on the deformation properties. Distinctly different deformation properties were observed between grouted and ungrouted samples. Untreated samples developed very little axial strain after only a few cycles and prior to the onset of liquefaction. Once liquefaction was triggered, large strains occurred rapidly and the samples collapsed within a few additional cycles. In contrast, grouted sand samples experienced very little strain during cyclic loading. What strain accumulated did so uniformly throughout loading and the samples remained intact after cyclic loading. In general, samples stabilized with 20 weight percent colloidal silica experienced very little (less than two percent) strain during cyclic loading. Sands stabilized with 10 weight percent colloidal silica tolerated cyclic loading well, but experienced slightly more (up to eight percent) strain. Treatment with

colloidal silica grout significantly increased the deformation resistance of loose sand to cyclic loading.

Groundwater and solute transport modeling were done using the codes MODFLOW, MODPATH, and MT3DMS. A "numerical experiment" was done to determine the ranges of hydraulic conductivity and hydraulic gradient where passive site remediation might be feasible. For a treatment are of 200 feet by 200 feet, a stabilizer travel time of 100 days, and a single line of low-head (less than three feet) injection wells, it was found that passive site remediation could be feasible in formations with hydraulic conductivity values of 0.05 cm/s or more and hydraulic gradients of 0.005 and above. Extraction wells will increase the speed of delivery and help control the down gradient extent of stabilizer movement. The results of solute transport modeling indicate that dispersion will play a large role in determining the concentration of stabilizer that will be required to deliver an adequate concentration at the down gradient edge. Consequently, thorough characterization of the hydraulic conductivity throughout the formation will be necessary for successful design and implementation of passive site remediation.

The cost of passive site remediation is expected to be competitive with other methods of chemical grouting, i.e. in the range of $60 to $180 per cubic meter of treated soil, depending on the concentration of colloidal silica used.