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title: **Grout curtain construction using bentonite for the control of groundwater seepage and contaminant migration**

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BACKGROUND

The contamination of groundwater resources from point or extended sources has been a source of worry to groundwater users and researchers. Identifying the contaminated source and clearing it from spreading could be the best way of addressing contamination issues. However, this might not be very effective as some traces could still be left behind. The only way to prevent potential sources from spreading as corroborated by many researchers is to construct a vertical barrier to block water or leachate from entering or leaving the contaminant source respectively.

Grout curtains are vertical, low permeable grout walls constructed in the ground to block horizontal fluid flow. They are constructed by injecting grout at certain pressure directly into the soil or rock through drilled holes at closely spaced intervals such that each plume or "pillar" overlaps the next, thus forming a continuous wall or curtain. The injected grout permeates through the soil thereby sealing the pores and cavities resulting into low permeable barrier. In most cases, vertical barriers are constructed by *in situ* mixing of cement and soil in deep trench to form the barriers. However, constructing such barriers at great depths below the ground surface may be limited by the capability of the trenching equipment. This method requires heavy machinery which may be capital intensive and environmental unfriendly. However, in grout curtain, the grout can be injected to considerable depths which can also penetrate tiny pores of the soil or fractured rocks of small aperture sizes.

A laboratory test on the suitability of using bentonite grout for the construction of vertical barriers was investigated. In this research, grout injection into artificial rock fracture and porous medium (river sand from Okayama area of Japan) using Salt/bentonite slurry was conducted. The paper discusses how a grout curtain can be constructed in the saturated-to-unsaturated soil and rock conditions to ensure complete containment of contaminant.

CRITICAL HYDRAULIC GRADIENT

Barrier thickness is a determining factor to the effective performance of the barrier. The design of the thickness wholly depends on the critical hydraulic gradient of the bentonite used. This implies that, prior to the construction of grout curtain, it is important to determine the critical hydraulic gradient. The critical hydraulic gradient is the hydraulic head beyond which a failure of the barrier occurs. This is given by the relation

$$\frac{\Delta h}{L} < I_C$$

where Δh is the effective hydraulic head, L the thickness of the barrier and I_C is the critical hydraulic gradient which can be determined experimentally.

APPLICABILITY AND LIMITATIONS

Grout curtains may be used up-gradient of the contaminated area, to prevent clean water from migrating through waste, or down-gradient, to limit migration of contaminants. They may also be used as cut-off wall for groundwater storage in underground dams. However, effectively creating a wall without defects has been problematic in certain environments and operating conditions. Especially, if very coarse-grained materials are encountered, defects in the curtain may occur. The site must be well characterized to minimize unexpected geologic conditions.

METHODOLOGY

The method involved injecting salt/bentonite slurry at Liquid/Solid (L/S) mixing ratios of 6, 8 and 10 into cylindrical columns of compacted river sand of porosity ($0.33 \leq n \leq 0.40$). The resulting grouted columns were then set up for permeability test with subsequent determination of critical hydraulic gradient. Determination of the critical hydraulic gradient involved running the permeability test for a long time while maintaining a given hydraulic gradient and the permeability determined with time until a constant permeability was attained. Measurement continued at stepwise increase in hydraulic gradient till failure occurred where the permeability was observed to increase with time.

Similar injection was conducted on artificial fracture of aperture sizes 60, 80 and 100 μm and the critical hydraulic gradient determined.

RESULTS AND CONCLUSION

The results showed that grout of the given mixing ratios was successfully injected into compacted river sand and artificial fracture. The critical hydraulic gradient for the compacted sand was between 180 and 200 while that for the grouted fracture was between 30 and 35. It is thus safe to use the lower values of critical hydraulic gradient of 180 and 30 for sand and fracture respectively in calculating for the barrier thickness. The permeability values for the porous media was in the range of 10^{-9} cm/s while the values for the grouted fracture in the range of 10^{-6} to10^{-7} cm/s which are recommended for seepage barrier.

The critical hydraulic gradient for porous media is thus higher than for fracture medium. The lower value for the fracture could be due to the smooth nature of acrylic used for the fracture model. A rough surface is thus recommended that may mimic fracture conditions on the field.

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