Design and Control of Slurry Wall Backfill Mixes for Groundwater Containment

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ABSTRACT: For the last several decades, the use of slurry cutoff walls for the containment of contaminated groundwater have proven a cost-effective remediation technology. The proper design of the final backfill for these cutoff walls is dependent on a variety of requirements that include: permeability, strength, density, compatibility with contaminants, soil/groundwater conditions, and of course, cost. After proper selection and design of an appropriate backfill mix, quality assurance/quality control (QA/QC) of this material is essential to produce repeatable results consistent to that achieved during initial laboratory bench-scale testing. Here in the United States, a majority of the slurry wall backfill mixes in the past have consisted of either soil-bentonite or cement-bentonite backfill. Recently, the development of soil-cement-bentonite backfill mixes has taken place, particularly for the strengthening of levees. In addition, during the past few years, there has been significant increase in the use of extremely low permeability self-hardening slurries. Based on over twenty years of actual field experience, this paper summarizes: design considerations for slurry wall backfill mixes based on site conditions and performance requirements; typical design mixes utilizing various combinations of soil, bentonite, attapulgite bentonite, cement, slag cement and a variety of admixtures; and advantages/ disadvantages of various backfill mixes and proper QA/QC procedures to be utilized in the field.

Since the 1940's, slurry cutoff walls have been used in applications for the containment of groundwater. During the 1980's slurry walls were implemented to contain contaminated groundwater on environmental sites. Permeability is the typically the primary concern for regulators; however, from a design point and based on site conditions, there are often other parameters of equal concern for the design engineer, including cost and constructability (i.e. can it be built?). For example, assume your soil profile includes a layer of very low density, high organic peat, and the required alignment is subject to differential lateral loads due to grade changes at the site. A standard soil-bentonite backfill may be too dense, resulting in a significant overrun in backfill quantities and may fail due to a lack of necessary shear strength. A soil-cement-bentonite backfill, if blended with the on-site organic soils, may never gain the required strength due to the presence of the high organic soils, and a cement-bentonite backfill may meet the constructability concerns, but may not meet the required regulatory permeability requirements. Hence, the need for a properly designed backfill mix.

There are two distinct types of slurry wall backfill mixtures, self-hardening slurries and soil-based backfills. Self-hardening slurries typically contain water, clay (bentonite or attapulgite) and cementituous materials (Portland cement or slag cement). The slurry is prepared in an on-site slurry batch plant and pumped to the trench via pipes/hoses. The slurries are introduced into the trench in one of two ways; either as the trenching slurry as well as the backfill, or by tremie method through bentonite slurry that is used to stabilize the trench sidewalls.

Self-hardening slurries can be used to achieve the highest compressive strengths, lowest permeabilities, or an efficient combination of strength and permeability. These slurries are

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applicable when the work area is tight, when excessive backfill density is a concern, when trench stability cannot be attained with a typical bentonite slurry or when compressive strength is required. Cement-bentonite is the most common.

Soil based backfills, as their name implies, are primarily comprised of soil, either the excavated materials, borrow, or a combination of both. Clay (bentonite or attapulgite), cement, or a combination of both is added to the soil via sluicing with slurry and dry addition, if required. These slurry walls are supported by a clay-based slurry during excavation. Backfill is prepared by mechanically mixing the materials at the surface.

A primary advantage is the elimination of disposal by incorporating the excavated material into the backfill, however, a relatively wide and flat working surface is required. If the workpad width is not acceptable, remote mixing of the backfill is an option. If site soils are acceptable, work space is available and compressive strength is not a requirement, soil-bentonite achieves the lowest permeability for the cost. Attapulgite may be substituted for bentonite in saline environments. Soil-cement-bentonite is being used on levee upgrade projects because it achieves low permeability and strength in the range of 50 psi.

Table 1 presents a summary of some of the typical parameters that should be considered during the design of slurry wall backfill mixes. These parameters include: permeability, strength, density and relative cost. Other critical factors include acceptability of site soil for use in backfill, trench stability, compatibility, available work area, water availability, longevity and availability of off-site backfill materials (if required).

BACKFILL MATERIAL	**PERM (cm/sec)**	**UCS (psi)**	**DENSITY (pcf)**	**COST ($/vsf)**	**COMMENT**
Soil-Bentonite	1×10^{-7}	0	100-130	3-6	Requires min. 15% fines
Soil-Attipulgite	1×10^{-7}	0	100-130	3-6	For saline environments
Soil-Cement-Bentonite	5×10^{-7}	50	95-120	5-10	Typically remote mix
Cement-Bentonite	1×10^{-6}	25	70-75	6-12	Self-hardening slurry
Slag cement-Bentonite	5×10^{-7}	100	69-72	6-12	Self-hardening slurry
Impermix™	1×10^{-9}	100	69-72	8-16	Self-hardening slurry
Composite w/Liner	1×10^{-10}	N/A	N/A	7-14	Depth Limitations

Table 1 - Typical Parameters of Common Slurry Wall Backfill Mixes

Based on initial screening, often bench-scale testing is performed to confirm the required mix design will meet the required parameters, and if necessary to confirm the compatibility of the backfill material with know site contaminants. The typical cost of this testing is in the $10,000 range. Compatibility testing is usually based on qualitative visual observations of the slurry and backfill materials in contact with site groundwater and with regular tap water as a reference.

For initial guidance, Tables 2 and 3 summarize typical proportions of the various backfill components. Table 2 includes the self-hardening slurries with proportions presented as a percent of total weight. Table 3 summarizes soil-based backfills with typical addition rates of clay and cement as the percentage of dry weight to weight of soil. A sufficient amount of slurry is sluiced with the soils to achieve a 2 to 6 inch slump, measured with a standard concrete slump cone.

Backfill Material	Bentonite	Attapulgite	Cement	Slag Cement	Water
Cement-Bentonite	4-6	-	12-20	-	75-84
Slag cement-Bentonite	2-4	-	0-5	9-15	80-85
Impermix^{TM}	-	4-7	-	7-16	80-85

Table 2 - Typical Proportions of Self-Hardening Slurry Wall Backfill Mixes

Backfill Material	Bentonite	Attapulgite	Cement
Soil-Bentonite	1-5	-	-
Soil-Attipulgite	-	1-5	-
Soil-Cement-Bentonite	2-3	-	4-10

Table 3 - Typical Proportions of Soil-Based Slurry Wall Backfill Mixes

Once a proper backfill mix has been selected and bench-scale testing using proposed materials has been performed, proper QA/QC of this material is essential to produce repeatable results in the field. In the field, the use of easily performed API and ASTM specified tests to provide the necessary QA/QC of the slurry and backfill mixes is necessary to confirm slurry and backfill requirements are met. These tests include fines content, density, pH, viscosity, filtrate loss and slump. Other documentation would include batch mix proportions and logging confirmatory test samples.

With the availability of qualified testing laboratories, critical parameters such as permeability and strength are often best performed by local testing laboratories. Depending on the project, a variety of standards such as ASTM and the Army Corps of Engineers standards may be utilized. Due to the sensitive nature of these samples, the sampling, preparation, storage, handling and shipping of these samples are an important responsibility of the on-site QA/QC engineer. Since the testing of slurry wall backfill samples can have some differences when compared to standard testing of geotechnical samples, the testing laboratory should be made aware, up-front of potential factors. In critical situations, the QA/QC engineer should consider having initial test samples tested for comparison with previously tested split samples from another pre-qualified and approved laboratory. New testing laboratories should be initially audited. The procedure of QA/QC split-sampling and archiving of samples is prudent.

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