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INSTALLATION OF A DEEP DRAINAGE TRENCH BY  
THE BIO-POLYMER SLURRY DRAIN TECHNIQUE  

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INTRODUCTION  

An underground diesel fuel spill at a county bus maintenance facility in San Jose, California was successfully remediated by constructing a pair of 50 feet deep, gravel-filled extraction trenches. Well casings with ejector pumps were set into the trenches for withdrawing the diesel fuel contaminated groundwater to a small, onsite treatment plant. Severe access restraints, the proximity of major structures, and heavy traffic demanded a quick, yet safe construction technique for installing the deep trenches.

The drainage trenches were installed by the innovative use of a modified version of the slurry trench technique using a biodegradable slurry, i.e. the bio-polymer slurry drainage trench (B-P Drain) technique. A bio-polymer slurry was used instead of bentonite slurry to temporarily support the trench walls without structural bracing. Upon completion of backfilling, the slurry in the trench was chemically reduced to water and simple sugars to activate the drain. The entire trenching and backfilling operation, including well placement, was completed in about two weeks.

Site Description  

The site of the project was an active bus maintenance facility that included a large maintenance garage, office complex, parking for more than 200 busses, underground fuel storage and automatic bus wash (see Fig. 1). Due to a historical spill or an undetected leak, diesel fuel was discovered in monitoring wells onsite and the plume was expected to eventually breach the property line.

The soil stratigraphy underlying the site consists primarily of interbedded native sands and cohesive soils (see Fig. 2A). The bedding of the sand layers is at least partially discontinuous, which is reflected in a phreatic surface that varies from 30 to 35 feet deep.
Studies by the consultant (Ref. "Don Pedro, Choboya Station, Diesel Spill Remediation Alternatives", EMCON Associates, January 7, 1987) indicated that a deep, continuous drainage trench with extraction wells could be used to intercept the plume and collect the contaminated groundwater. The interceptor trench design called for a two layered filter with a granular material overlying, a graded sandy gravel filter. Wells were spaced at approximately one hundred foot intervals (See Fig. 2B). Interference from existing structures complicated placement of a continuous trench. This was solved by using two parallel trenches on opposite sides of the interfering structures.

The first trench was designed to be 350 feet long and 44 feet deep and ran along the north side of the garage. The second trench was 240 feet long and 46½ feet deep and ran along the south side of the office complex, down the middle of an access road 15 feet from the property line. At the closest point the trench was 50 feet from the nearest structure.

Bio-Polymer Slurry Drainage Trench Technique

For this project, a major cost savings was realized by using the B-P Drain technique to install the trenches. Several similar trenches had been previously installed in Europe to intercept groundwater and thus strengthen unstable highway and railroad slopes. This application was a natural extension of the technique's potential into the interception of contaminated groundwater.
Fig. 2: Existing Soil Profile and Profile of Interceptor Trench

Basically, the B-P Drain technique is an extension of the slurry trench technique which uses a biodegradable slurry instead of bentonite to maintain trench stability. Conventional slurry trenches are excavated under a bentonite slurry which seals the trench walls and transmits the higher hydrostatic pressure in the trench to the trench walls and thus provides stability. Stability of conventional slurry trenches is assured by maintaining a positive differential slurry head in the trench over the groundwater table and by successfully maintaining the required bentonite slurry properties.

When creating a drain, sealing of the trench walls would be counter-productive so a guar gum-based slurry was selected in lieu of bentonite. Guar gum is a natural organic polymer derived from the guar bean, a plant grown principally in India. When properly ground and mixed with water a biodegradable, pseudo-plastic slurry results which performs like a drilling fluid.

The primary limitation of guar gum slurry is that its effective life is about one day. Unchecked, guar gum naturally deteriorates due to enzyme action leaving only water and simple sugars which are consumed by micro-organisms in the soil. Also, guar gum does not form a filter cake or display filtrate properties like bentonite. Therefore, a high gel strength is critical in guar gum slurries to permit the transfer of the hydrostatic pressure from the slurry to the trench walls.

A bio-polymer slurry is created by adding preservatives to the guar gum during hydration while simultaneously controlling slurry chemistry. The bio-polymer slurry will, with subsequent retreatment, remain active for
one to two weeks. The effective life of the slurry is a function of soil and groundwater chemistry, temperature, and the frequency and type of retreatment.

Quality control of the bio-polymer slurry revolves around maintaining the slurry in an active state during excavation. The standard slurry properties of viscosity, unit weight, filtrate and pH are monitored. The properties of the bio-polymer slurry can be adjusted within limits using chemical additives.

Prior to field implementation of this project a laboratory testing program was performed to evaluate the various slurry ingredients and to set quality control guidelines for the proportioning of the various additives. Figure 3 shows the relationship between slurry viscosity, pH, and filtrate with time. On approximately the eighth day, the bio-polymer slurry begins to naturally breakdown as shown by the decrease in the pH and large increase in filtrate. The viscosity, however, remains consistent until the twelfth day, indicating that while the slurry is no longer functional, more breakdown must occur to activate the drain.

![Graph showing viscosity, pH, and filtrate over time](image)

Fig. 3: TIME TO NATURALLY BREAK BIO-POLYMER SLURRY AS A FUNCTION OF VISCOSITY, pH, AND FILTRATE
Figure 4 shows the result of chemically reducing a second bio-polymer slurry with the breaker solution. The permeability of the drain is restored almost immediately after the breaker solution is added. The change in the viscosity of the bio-polymer closely mirrors the change in permeability of the drain. This result is useful in the final stages of construction when the slurry is reduced to water. By monitoring viscosity, the complete breakdown of the slurry can be confirmed and activation of the drain realized.

![Graph showing permeability and viscosity changes](image)

**Fig. 4: CHANGE IN PERMEABILITY OF SAND FILTER MATERIAL IN COMPARISON WITH BREAKDOWN OF BIO-POLYMER SLURRY**

**B-P Drain Verses Conventional Trench Construction**

When the B-P Drain technique was compared to conventional construction for the San Jose project, a number of practical, technical and cost advantages were evident. The width of the proposed conventional trench was specified at a minimum of six feet, but was expected to be about twice as wide to accommodate personnel and equipment working in the trench and the bracing necessary to stabilize the trench. The B-P Drain could be constructed three feet wide thus minimizing disposal costs for the trench spoil and the corresponding volume of gravel used to fill the trench. Since the driving and extraction of sheet piles was eliminated, project noise and vibration was minimized. The elimination of sheet piles also precluded the possibility of creating slickenslides on the trench walls by smearing the interbedded sands and clays and thus altering the hydraulic conductivity of the native soils.
Since all work was performed from the surface under slurry, the possibility of exposure to project personnel from hazardous materials was minimized. Accordingly, dermal and respiratory protection was unnecessary. Entry into the slurry filled trench was obviously impossible so the stability of the trench could not threaten workers.

CONSTRUCTION

Slurry Mixing

The bio-polymer slurry was mixed in a modified colloidal mixer as shown in Fig. 5. Experience during project start-up showed that a high speed colloidal mixer, typically used for bentonite slurry, could not adequately disperse the guar gum in water. Accordingly, the colloidal mixer was modified with a particle-dispersing vane which successfully eliminated partially hydrated particles and produced a workable slurry. Guar gum was added at the colloidal mixer, while the preservatives and chemical additives were added both at the mixer and at the holding tanks, depending on quality control requirements. The solution was continuously mixed and pumped to storage in four 20,000 gallon frac tanks. A centrifugal pump was used to recirculate each frac tank prior to discharge to the trench. The large storage volume permitted the mix plant to supply both individual batches and/or a continuous flow of fully hydrated slurry.

![Fig. 5: BIO-POLYMER SLURRY MIX PLANT](image)

During the course of mixing and circulating the slurry, the rheology and chemistry of the solution were frequently monitored and adjusted as needed to assure preservation of the guar gum. With only minor adjustments, the viscosity of the slurry was maintained at or above the original design viscosity while it was in use.
Trench Excavation

Both trenches were excavated using a Koehring 1266 hydraulic excavator, equipped with an extended stick and a bucket three feet wide (see Fig 6). Excavated soils were deposited on the surface, upslope from the excavation so that excess slurry could drain back into the trench. Later, all excavated trench spoil was hauled offsite. The rate of excavation was limited by the volume of slurry that could be pumped into the trench, since it was desirable to maintain the slurry level near the surface to maintain trench stability.

![Fig. 6: TRENCH EXCAVATION](image)

The initial trench, 350 feet long, was excavated in three alternating panels, two primary panels on the outside and the secondary panel in between. The panel lengths were governed by the volume of material that could safely be excavated in one day. It was conceivable that the excavation could have been completed quicker, but the volume of slurry consumed would have been impractical, so a balance was achieved.

Excavations were deepened three feet where the 12 inch steel casings were to be inserted, three casings in the first trench, two in the second trench 240 feet long. Following excavation and before backfilling, stop-end beams three feet wide and 50 feet long were inserted to support the primary backfill when the secondary panel was excavated.

Panel construction was accomplished by simultaneous excavating and backfilling the alternating panels. Figure 7A shows the filter material being placed in the first panel while excavation proceeds in the second panel. As backfilling proceeds (Fig. 7B), the slurry is reused by displacing the slurry with the granular material from a panel being
backfilled to a panel being excavated. Figure 7C shows backfill being placed around the wells. Finally, in Fig. 7D, the stop-end beams are removed and a continuous section of drain is completed.

Fig. 7: SEQUENCE OF DRAIN CONSTRUCTION USING B-P DRAIN TECHNIQUE

Bentonite Seal

The conventional trench design called for placing a dry bentonite seal on the bottom of the excavation to separate and seal the trench bottom. Because of the impracticality of spreading dry bentonite through a viscous slurry, a blend of viscous sand-bentonite was placed along the bottom of the trench. The sand-bentonite was placed by the excavator bucket through the slurry and gently spread in a uniform procedure along the bottom. The layer was intentionally made thicker than the specified six inches, to account for irregularities in the method of placement.

Well Casings

Where the casing locations were indicated, the trench was deepened to accommodate the thicker trench seal. Screened intervals 10 and 14 feet long were welded into the casing which was lifted and set vertically in place, then braced so that no lateral movement could occur during subsequent backfilling (see Fig. 8). The viscosity of the slurry prevented fluids from entering through the screened interval, giving the casing a tendency to float. Therefore, the casings were gradually lowered into place by adding fresh water into the top of the casing as a ballast.
Fig. 8: WELL INSTALLATION

Backfill

In order to minimize clogging of the drain, a graded backfill was installed. The use of a two-layered backfill required a separate placement system for each layer. First, a California Class 2 permeable material (graded sandy gravel) was placed on the bottom 10 and 14 feet of the trenches to coincide with the screened interval in both trenches. It was elected to deliver the filter material in cement trucks for direct placement into tremie hoppers connected to tremie tubes that extended to the bottom of the trench. This procedure minimized segregation of the filter material, as opposed to end dumping from above. The use of cement trucks was a more costly measure, but given the limited working area available, it turned out to be a distinct advantage. The filter materials were wetted prior to placement to eliminate air pockets, and allow the mixture to pour more smoothly through the tremie tubes.

The remainder of the backfill consisted of a gravelly sand with 1½ inch maximum particle size. This material was deposited directly into the slurry filled excavation by a front end loader to complete the backfilling. This procedure allowed a balance to be achieved in slurry
displacement between the backfilled panel and excavation of the successive panel. When the following panel excavation proceeded slower than the previous panel backfilling, the backfilling was simply slowed to balance the slurry level, and conversely.

The thickness of the granular material exceeded the planned thickness to accommodate the slurry trench method. By placing granular fill to the top of the trench, any settlement potential within the trench was reduced. Later, the upper four to six feet of the trench were removed to install the utility piping between casings (See Fig. 9) and to a treatment plant. The exposed trench bottom and all backfill above the utility lines were mechanically compacted.

**Fig. 9: INSTALLATION OF EXTRATION WELL UTILITIES**

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**Disposal of Excess Slurry**

Fresh slurry was prepared for each of the trenches. The advantage of panel excavation and subsequent reuse of slurry in each panel was that less slurry was required. During backfill of the final panel in each trench, the displaced slurry was pumped from the trench to one of the holding tanks. Within this holding tank, degradation of the slurry was accelerated as planned by readjusting the slurry chemistry and adding a breaker solution. The solution was then circulated through the system of
pumps previously described. Once sufficiently reduced and laboratory tests proved no contamination was present, the slurry was disposed of by directly pumping it into the storm sewer system. Soil particles that accumulated in the bottom of the frac tanks during slurry breaking were hauled offsite.

In order to break the slurry remaining in the backfilled trench, submersible pumps were inserted into the casings to extract any slurry that may have entered through the well screens. In addition, both fresh water and a breaker solution were injected into the casings and circulated within the filter material in a procedure that is analogous to developing a well. The fact that sufficient volumes of fluid were extracted demonstrated that the system was functional.

Project Completion

Together, the trenches were completed in two weeks. Busses were able to pass over the trenches immediately after completion, facilitated by strategically placed trench plates. Rapid completion of the drain was followed by an orderly installation of the utility connections from the wells to the treatment plant. The pavement was then restored allowing unimpeded access. The startup of the activated-carbon treatment plant was successful and the entire extraction trench/treatment facility has since performed as expected.

FUTURE CONSIDERATIONS

This particular project was so successful and cost-effective as to promote active discussions among the participants into ways to better exploit the B-P Drain technique. The installation of a graded filter, while appropriate, created a few situations and was time consuming. On a subsequent project, a single backfill material that could be end-dumped was used in lieu of a two-layered backfill. This was feasible because of the more uniform nature of the native soils. On future projects, it may be possible to protect the filter material from clogging by installing a woven geotextile between the trench wall and the backfill. Durable woven geotextiles are purported to be suitable as hydraulic gradient resistant filters for a wide variety of soils. Research is presently in progress in order to determine the compatibility between the bio-polymer slurry, geotextiles and various filter materials.

On very deep drains such as this project, deep wells and interceptor trenches are preferred. On more shallow drains, it may be possible using the same technique, to install a horizontal drainage tubing to serve as a gravity drain and transmit groundwater to a central collection point.

CONCLUSION

The installation of a deep interceptor trench can be successfully performed by the bio-polymer slurry drainage trench technique. B-P Drains are installed from the surface, using a biodegradable slurry to
retain the narrow excavation while permitting simple placement of materials and structures in the trench. Carefully monitoring the rheology and chemistry of the slurry, along with the addition of slurry control agents, keeps the slurry functional while the work is in progress. Once the work is complete, the slurry degrades both naturally and, as assisted by a breaker solution, to water and simple sugars, activating the drain.

This new application of a little known technique, to a difficult waste remediation project, resulted in a safer, quicker, and less costly solution. The combination of slurry trench technology and bio-polymer chemistry allowed the construction team to avoid the pitfalls of conventional braced excavation construction and shorten the expected project duration from many months to a few weeks.