FINAL REPORT OF DSM DEMO PROGRAM AT TVA KINGSTON ASH RECOVERY PROJECT

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INTRODUCTION

In April 2010 Remedial Construction Services, L.P. was awarded a contract to execute a DSM Demonstration Program at the TVA Kingston Ash Recovery Project , Harriman, TN 37748.

In December 2008, the fly ash pile had moved due to slippage failure of the underlying soil layer and had caused an environmental impact. TVA is executing a multimillion dollar project to mitigate the effects of this incident. As part of this project it is proposed to construct a barrier along the perimeter of the Dredge Cell (See figure 1-2-Attachment 1) to contain the soil and fly ash from the plant. It is proposed to construct the barrier by installing DSM columns/panels from existing grade to the weathered rock below and then construct a dyke on top of the DSM barrier that will contain the fly ash (Attachment 1).

The general stratification at site consists of basically 3 layers – fly ash, clay & silty sands above the weathered shale overlaying the bed rock at about 70 ft below grade. The fly ash layer is supposed to be about 35 ft thick, the clay layer about 10 ft and the silty sands layer about 25 ft. While DSM technique has been successfully used to stabilize clays and silty sands in numerous projects, stabilizing fly ash by DSM technique is being tried for the first time at this project.

The DSM demo program called for installing DSM columns to construct a panel 20ft long 7ft wide to the underlying weathered rock/bed rock layers. The requirement was for the DSM to achieve a 28 day UCS of 150psi.

RECON proposed to install 2 rows of DSM columns, each column 5.0ft in diameter spaced at 4ft center to center to create a panel of 7.0ft width. A total of 11 columns were proposed to be installed (Attachment 2).

Based on Bench tests conducted on samples of Fly Ash, Clay & Silty sands from the site to determine the dosage of reagent required RECON recommended using a dosage of 289lbs of Portland cement per CY of materials for the full depth of the column (Attachment 3).

RECON installed the DSM columns using a 5.0ft dia drilling tool attached to a hollow drill stem driven by a DELMAG RH-26 Drill Rig.

Wet grab samples at designated depths from each column were collected and cast into sample cylinders 3” x 6” and tested at a TVA designated laboratory for 28 day UCS, Hydraulic Permeability & tensile strength.

Cores were extracted from selected columns and tested for 28 day UCS, Hydraulic Permeability & tensile strength.

Based on the results it can be concluded that DSM can definitely be used to stabilize the Fly Ash at this site.

Other aspects regarding the suitability of DSM are discussed in the following pages-

DSM CONSTRUCTABILITY

The DSM demo program has clearly demonstrated that DSM is a very good solution to meet the requirements of the design to provide a sound retaining barrier along the perimeter of the dredged cell to prevent recurrence of a slip failure.

The RFP for the Demo program required the DSM columns to penetrate 2 ft into bed rock.

RECON had stated in their proposal – Section 4 – Other- Alternate Termination/ Mixing Tool Criterion- "*RECON will use a specially fabricated drilling tool fitted with Tiger Rock teeth (both single and twins). This tool should be capable of drilling 2- feet into the weathered shale, as called for in the specifications.*

However, if the drilling tool penetration into the weathered shale layer is less than 1-inch per minute, it will be considered that resistance to drilling has occurred and the drill tool will be withdrawn at that depth."

During execution there were a number of discussions to clarify this position. In DSM technology it is very difficult to establish the exact depth at which the rock layer has been met. The industry practice is to define a refusal criterion where rock layer is expected and the DSM column is required to be terminated in such layer, as it is very difficult to establish the depths at which rock layer will be met, without borehole data at very frequent intervals of say 50 ft.

On the request of the consultant to the project RECON replaced the 9" Quad Dirt Pilot Bit that was being used with a RP4 Pilot Bit. This change also did not help in greater penetration. Most of the times when the DSM column was terminated it was observed that the drill stem was spinning at the same location and the penetration was less than 0.2" or 0.3" per minute.

TVA arranged to drill 2 bore holes on either side of the DSM column locations. The rock strata were identified by the borings and the plot of the DSM columns against the rock strata indicates that the DSM columns installed had penetrated sufficiently into the rock layer (Attachment 8).

It may be noted that anchoring DSM columns into rock layers may not give any advantage to the DSM as the shear strength of DSM is very low and DSM cannot be designed as a cantilever to take advantage of the anchoring in the bed rock.

At this site basically there are 3 identifiable layers of materials to be stabilized by the DSM technique. They are the top ~35 ft of Fly Ash, over ~10 ft of Clay, over ~25 ft of Silty sands. DSM has proved in innumerable cases that clays and Silty sands can be stabilized to achieve reasonable 28 day UCS. RECON has executed projects where similar clays and sands were stabilized to >300 psi. On this DEMO program the main question in everybody's mind was the feasibility of stabilizing the FLY ASH at site to reasonable 28 day UCS with a suitable reagent, in this case Portland cement.

Though the wet grab samples indicated that the 28 day UCS were less than the required 150psi, the cores have indicated that the 28 day UCS have been greater than the required 150psi. Even a visual examination of the cores from the Fly ash zone indicated the effectiveness of the DSM technique to stabilize the Fly ash. The difference in the sample strength can be attributed to the environment in which the samples were cured. The samples allowed

to cure in situ were insulated from the loss of heat of hydration and moisture. The curing effects of heat of hydration and moisture are well known as they relate to Portland cement. In fact RECON's standard procedure for bench testing of stabilization samples includes maintaining 100 percent humidity and 100 degrees temperatures for three days to sufficiently emulate field conditions.

RECON is of the opinion that DSM is definitely an acceptable technique to adopt for the improvement of the perimeter of the Dredge Cell as envisaged in Figure 1-1 to 1-5.

MIX DESIGN PARAMETERS

Based on the bench test reports (Attachment 3) – See summary of bench test reports below-

	PORTLAND CEMENT DOSAGE -% BY DRY WEIGHT											
	7.50%				10.00%				12.50%			
Material	7 Day UCS	14 Day UCS	28 day UCS	Hyd. Cond.	7 Day UCS	14 Day UCS	28 day UCS	Hyd. Cond.	7 Day UCS	14 Day UCS	28 day UCS	Hyd. Cond.
Fly Ash 81.4 pcf	65	74	84	5.40E-06	77	101	128	4.90E-06	89	121	159	3.70E-06
	64	73	82		80	94	128		91	119	160	
Clay 107.3 pcf	148	187	211	1.70E-08	237	291	360	1.60E-08	323	394	442	1.10E-08
	154	177	225		226	302	368		320	375	453	
Silty Sand 99.8 pcf	114	142	148	9.30E-08	148	169	196	8.40E-08	198	223	261	7.70E-08
	120	137	156		144	172	194		186	219	280	
Blended 93.4 pcf	94	118	187	5.00E-08	132	166	276	3.30E-07	155	214	333	2.40E-07
	90	118	202		132	174	276		149	207	343	

RECON, recommended to try 2 dosages in the DEMO program-

289.71lbs/CY and 362.14 lbs/CY.

These are 10% and 12.5% of dry weight of Clay (107.3pcf)

The 289.71lbs/Cy dosage works out to 10% for the clay, 13.18% for the Fly Ash & 11.48% for the Silty Sand.

The 362.14lbs/Cy dosage works out to 12.5% for the clay, 16.48% for the Fly Ash & 13.44% for the Silty sand.

During execution TVA desired to try a dosage of 7.5% or 217.28lbs/CY instead of 12.5% that was done.

Based on the UCS results from the cores it can be concluded that a dosage of ~ **290-300lbs/CY** should be capable of achieving the specified **28 day UCS of 150 psi**.

Tool penetration rates of 1.5 ft/minute to 2.0ft/minute and rpm of 20 or higher should be sufficient to produce uniform soil cement mixture.

The clay layer may need additional mixing energy that can be imparted by reducing the penetration speed in that zone or repeated mixing of that zone.

Based on a dosage of 300lbs/CY, the grout injection rate- with a W/C of 1.0- works out to **47.37 GALLONS /CY**.

OPTIMIZING THE CONSTRUCTION SEQUENCE FOR THE PRODUCTION PHASE

Assuming the Conceptual design of the perimeter Improvements as in figure 1-1 to 1-5 (Attachment 1) is the final accepted solution-

The layout & diameter of DSM columns depend on the equipment proposed to be deployed by each agency quoting for the work. Smaller diameter columns will require additional rows to reach a stabilized mass of desires width.

ALTERNATE PROCEEDURES

DSM can be installed by single auger machines (as was done in the DEMO program) or multi auger machines. The selection of the number of augers, their diameter and other details depend on the type of equipment proposed to be deployed by each agency.

Another alternate technology that can be considered is cutter soil Mixing (CSM).

CSM utilizes a tool that creates a rectangular panel of soil cement. The tool is fixed to the bottom of a hollow drill stem. The 2 cutting wheels of the CSM rotate about horizontal axes and grout is injected as the CSM descends below the grade and mixes the soil layers loosened by the teeth on the cutting wheels. Depending on the size of the CSM used, rectangular panels of 7.87 ft x 1.8ft to3.28ft or 9.18 ft x 2.10ft to 3.93 ft, in plan can be mixed to the required depths. The panels are mixed in Primary-Secondary-Primary configuration. The overlap of the Primary and Secondary panels can be adjusted as required.

LESSONS LEARNED

- To have a crew that has all members trained in their designated duties, rather than depend on local workers expecting them to get trained on short duration jobs. On the major project there may be time to train local workers.
- TVA safety requirement of shutting down the job immediately a Storm/Lightning alert issued will seriously affect the job. Equipments are likely to be subjected to heavy damage if operations are not shut down in an orderly manner. Depending on at what depth the drill tool will be at the time of the shut down alert, shutting down may take between 30 minutes to an hour. This is a very serious matter and TVA has to come up with reasonable guidelines for shut down after a storm/lightning alert.
- For the main job reagent is to be stored in waterproof silos.
- Grout Plant components like Mixer, Agitator/Storage tank to be raised to allow easy access to the piping below.
- Real time data collection of all drilling parameters should be available. These must be capable of being printed and circulated quickly after the day's work.
- Frequency of sampling and coring to be decided. During the initial stages till reasonably good parameters are established frequency of testing may be high. Once the parameters are established the frequency may be relaxed.
- All measuring instruments- depth, flow, weights, rpm etc are to be calibrated at least once in a month in the presence of client's representative. Both client and contractor's representatives to sign off on the calibration records. Engaging a third party to certify the calibration at regular intervals will only add to the cost and schedule of the project.
- Specifications for the work platform are to be clearly specified. If contractors are not allowed acceptable industry practices, but have to follow specific requirement of the project, it should be clearly stated in the RFP.
- If DSM is to be installed in 2 or more rows adjacent to each other, it is general DSM industry practice to install the column/panels in one row and then move the rig over the installed DSM columns/panels and install the next row(s) within reasonable time after installing the earlier rows without waiting the earlier row of column/panels to attain full strength. Such delays will increase the wear and tear on the tools and will add to the time required to drill into the hardened columns/panels, which in turn will affect the project in cost and schedule.
- Generally optimum efficiency in DSM production is achieved when DSM contractors work 10-12 shifts of per week with each rig. This calls for other services that are not in contractor's scope to be available for such working.

ATTACHMENTS

- Attachment 1 – Figures 1-1 to 1-5 from RFP
- Attachment 2 – Layout of DSM Columns for Demo Program
- Attachment 3 – Bench Test Report to determine the Reagent Dosage
- Attachment 4 – Schematic of layout of DSM Equipments Set Up
- Attachment 5 – Lab reports of Field Samples
- Attachment 6 – Daily Installation Reports
- Attachment 7 – Photos from DSM Program
- Attachment 8 – profile of DSM Columns Installed and Rock Strata