Recycling Project: Concrete Grinding Residue

SCOTT GOODWIN AND MICHAEL W. ROSHEK

In spring 1990 the Utah Department of Transportation (UDOT) was responsible for disposing of 3,200 yd^3 of alkali solid waste and 891,000 gal of wastewater resulting from a large scale pavement grinding project (12 lane-mi on I-15). Numerous disposal methods were considered and reviewed for both cost and potential for success. Detailed laboratory testing was conducted as part of the preliminary investigation. UDOT worked closely with the Utah Division of Environmental Health in arriving at a solution. Ultimately, a decision was reached to recycle the solid waste into a road project, where it would serve as the mineral filler in a portland cement–treated base course. Disposal project phases included initial grinding, characterization of the waste material, heuristic evaluation of possible stabilization methodologies, wastewater treatment and solids interim storage, and final project design and placement. Care was taken to ensure that the material and wastewater were handled in an environmentally safe manner. Water was decanted from the grinding slurry, filtered to remove the suspended solids, and treated with sulfuric acid to lower the pH before disposal. A major emphasis in the pavement structural section design was to eliminate the possibility of future groundwater contamination on-site.

In August 1989, the Utah Department of Transportation (UDOT) had contracted to apply a proprietary polymer-modified concrete as a thin bonded overlay on 12 lane-mi of one of the busiest highways in Utah (128,000 AADT) (*1*), northbound Interstate 15 through Salt Lake Valley. The overlay's purpose was to eliminate ruts and rehabilitate a portland cement concrete (PCC) pavement that was almost 25 years old. The overlay varied from ¾ in. in the wear ruts to feather edge thickness at the lane lines.

The new overlay had been completed for less than a month when portions began to delaminate. After 4 months 15 percent had come off, and more was in the process of doing so. This project had been very high profile and controversial from inception. Consequently, media coverage had also been profuse, and anything related to the I-15 overlay was politically sensitive. When the material failed, the media's coverage became more extensive, and the political atmosphere became even more charged.

By April 1990, 6 months after initial placement, UDOT was involved in a full-scale grinding project to remove any remaining overlay as well as to correct the still-existent rutting and faulting of the original pavement. The grinding project generated 891,000 gal of alkali wastewater and 3,200 yd^3 of alkali solid waste, all of which required treatment and disposal.

Materials and Research, Utah Department of Transportation, 4501 S. 2700 W., Salt Lake City, Utah 84119.

GRINDING PROCESS

UDOT has, for many years, been involved in small-scale bump grinding projects of PCC pavement. But a grinding project of this magnitude, removing the overlay and the original concrete to an average depth of ¾ in. on more than 750,000 ft^2, was a unique experience.

With bump grinding, UDOT practice had been to allow the contractor to let the grinding slurry flow onto the shoulders or into the median swales. The project started out with the same concept; however, four grinding machines were mobilized for the project, removing considerably more material than the localized bump grinding. Because of the volume of material, the project was to be a turning point for this practice.

The overlay removal began on April 6, 1990. A few days later a representative of the Salt Lake County Health Department came on-site, took a grab sample from the end of the hose coming off the grinder, had the slurry water analyzed, discovered the total suspended solids (TSS) and pH of 12.0 to be substantially above acceptable limits, and had a restraining order in effect on April 11. The water was evaluated by Ford Analytical Laboratories. The results are given in Table 1. The high levels of heavy metals originated from the aggregate used in the overlay, which was slag from the Kennecott copper smelting process. It was also noted that a local hazardous site of cement kiln dust had similar characteristics. The project halted, and UDOT was instructed to "cease and desist" until it could devise and integrate a means for containing the slurry. A plan for final disposal of the slurry had to be developed, subject to final approval by the Utah Division of Environmental Health (DEH). In addition, instructions were given to clean up the slurry previously placed in the median and shoulders. Once containment of the grinding slurry was addressed, UDOT was allowed to continue grinding, with the understanding that completion of the disposal plan was pending.

GRIND WATER TREATMENT

Work was restricted for 10 days while agreements were being reached between UDOT and DEH. When grinding operations recommenced on April 21, the slurry was pumped directly from the grinder into on-site tanker trucks. The trucks then hauled the slurry to one of two sites for water treatment and temporary storage of the grinding sediment. (Initially, two storage sites were used. Circumstances, however, dictated the eventual movement of everything to a single site.) Both

TABLE 1 WATER QUALITY ANALYSIS COMPARISON*

Parameter	Concentration (ppm, except pH)	
	Off Grinder:	Values Acceptable to WWTP Before Discharge :
pH	12.6	7 to 9
TSS	> 50	45
Total Copper	1558	9.1
Total Arsenic	84.63	0.82
Total Barium	433	8.1
Total Chromium	132.37	4.0
Total Lead	318.99	5.0
Total Silver	1.09	3.1
Total Mercury	0.1787	0.03

*Tested by Ford Analytical Laboratories, Inc.

sites were decommissioned wastewater treatment plants (WWTPs).

On arrival at the storage-treatment sites, the tanker trucks discharged their loads into empty sludge drying beds. A hydraulic gradient was created, and the grinding water flowed across the adjacent beds, over or through the sidewalls, to the endmost drying bed. At this location the water was filtered through filter fabric twice, then pumped through a 200-μm screen into UDOT-manufactured bins, where sulfuric acid was added to reduce the pH. The sediment that remained was to be handled later. At this time a method for sediment disposal had not been agreed on by UDOT and DEH. A number of possibilities were still being considered.

As previously stated, the pH value of the slurry as it came off the grinder was high: 12.6. After sedimentation, filtration, and titration the pH of the slurry water was lowered to less than 8.5, well within the range (7.0 to 9.0) needed for delivery to the WWTP. Once the pH was acceptable, the water was pumped from the acid treatment bins into empty, recently washed tanker trucks and hauled to an operating WWTP for final discharge.

After UDOT treatment, the water was of such good quality that the highway agency would have had no difficulty meeting state water quality requirements for discharge. However, the constraint of a National Pollution Discharge Elimination System (NPDES) permit to allow us to do so arose. UDOT did not have the waiting time (60 to 120 days) necessary to apply for and receive one. Therefore, arrangements with an operating wastewater facility having a current NPDES permit were made.

After arrival at the WWTP, the grinding wastewater was discharged into the inflow and then through each of their unit operations and processes before ending up as effluent in the Jordan River, which flows into the Great Salt Lake. The water delivered was of better quality than the limits allowed for discharge from the treatment plant. Almost 891,000 gal were treated by this WWTP. The bill for treating the water was approximately $10,000. Costs will be discussed later.

MEDIAN AND SHOULDER CLEANUP

At the same time that grinding and water treatment were under way, a cleanup operation was under way in the median of I-15. Front-end loaders were removing the previously placed grinding residue, along with several inches of soil and gravel, vegetation, automobile parts, and miscellaneous debris; loading them into dump trucks; and hauling them away to one of the two storage sites. Approximately 1,600 yd^3 of material was removed from the median in this manner. A like quantity of grinding sediment remained in the sludge drying beds after water treatment and decanting.

TABLE 2 HYDROMETER ANALYSIS OF GRINDING RESIDUE

Size (MM)	Sieve	Percent Passing
4.750-------	#4	100.00
2.000-------	#10	92.38
0.425-------	#40	86.61
0.075------	#200	70.39
0.020		51.14
0.010		41.04
0.002		17.59
0.001		7.49

Specific Gravity: 2.59

More than 3,200 yd^3 of material had to be disposed of, half of which was a sludgelike material unlike anything UDOT had ever dealt with before. The pH was high, in the range of 12.0 to 12.6. The material contained large volumes of water, depending on the time elapsed since placement and subsequent evaporation. Moisture contents in the range of 140 percent were common. Size of the individual particles was similar to a silt or clay and is given in Table 2.

The material also displayed thixotropic behavior. During preliminary testing activities, buckets of the material were retrieved from the drying beds. While being shoveled, the grindings were semisolid, sticky, and plastic. Once back in the laboratory, however, subjecting the grindings to small amounts of mechanical agitation caused the material to return to the liquid phase in a matter of minutes.

Numerous suggestions were offered on how to deal with the solids. A few were seriously considered and examined. UDOT's major objective was either to stabilize the waste product solids, rendering them essentially inert, or to dispose of them in such a manner as to minimize the possibility of ever having them resurface as a future problem.

The options reviewed included the following:

1. Lower the pH of the grinding solids in situ and leave them in the sludge drying beds, where they would eventually

be covered over, becoming fill material for a future parking lot. This option required the drilling of observation wells to monitor groundwater for an indefinite period of time.

2. Lower the pH of the solids and haul them to a licensed landfill for disposal. Landfill personnel would monitor groundwater conditions indefinitely.

3. Leave the residue in the sludge drying beds and stabilize the particles into either a soil-cement mixture or a lean concrete mix, once again to serve as fill for a future parking lot. No groundwater monitoring would be required with this option.

4. Move the waste material from the present storage site as is and recycle it into a construction project.

Option 2, taking the waste to a landfill, was almost immediately rejected. The landfill fee was prohibitive, around $130,000. This left Options 1, 3, and 4. Options 1 and 3 were seriously considered and investigated: mix designs were determined; cylinders were made; 7-, 14-, and 28-day compressive strength tests were conducted; logistical and economical analyses were carried out; equipment was hired; test runs were performed; and so forth. Results of the various mix designs are given in Tables 3 and 4. At the same time, Option 4 was being investigated. A number of upcoming construction projects were being scrutinized for possible methods of grinding solids inclusion.

After numerous investigations and many meetings between UDOT and DEH engineers, the disposal method selected was Option 4, incorporation of the waste into a construction project. A project was on the drawing board that was just right: small enough to delay temporarily while the design was modified, yet large enough to use all of our grinding solids.

WASTE RECYCLING CONSTRUCTION PROJECT

All the solids were finally moved to one storage-treatment site. The 3,200 yd^3 of material were to remain at this location until being recycled into more than ½ mi of portland cement–treated base course (CTB).

The project selected for solids recycling incorporation was a 0.6-mi-long strength of frontage road west of Salt Lake City designed to accommodate heavy commercial truck traffic. Stations 182 + 47 to 206 + 50 (2,403 ft) exclusively were to contain the recycled solids. The solids were to go in the proposed pavement structure as mineral filler for a 12-in. CTB, permitting a reduction in the total thickness required. On top of this would follow 6 in. of granular borrow, 12 in. of untreated base course, 7.5 in. of bituminous surface mix, and 1 in. of plant mix seal.

The construction site was an alkali flat (a remnant of ancient Lake Bonneville): relatively level, high groundwater, high alkalinity, ponds of standing water, and salt-tolerant riparian vegetation. Drilling logs taken profiled the soil as ranging from sandy silt with gravel to clayey silt with sand, or silty clay. During drilling operations, groundwater would begin to enter the auger hole near 4 ft deep, and the zone of saturation would usually be encountered around 8 ft deep. Values of pH

TABLE 3 SOIL-CEMENT MIX DESIGN COMPRESSIVE STRENGTHS

Soil-Cement Mixes

Cement: Type II low alkali
Coarse Aggregate: grinding sludge

Compressive Strengths:

Cement content/cu. yd.	12 bag	11 bag	9 bag	6 bag	4 bag
Cure Time					
1 day	376	396	255	41	20
2 day	2250	837	238		
5 day				219	103
7 day	3979	1870	561		131
14 day	4416	2407	676	462	239
28 day	5411	3183	940	629	318

TABLE 4 CONCRETE MIX DESIGN COMPRESSIVE STRENGTHS

	SAMPLE NUMBER					
	NO. 1	NO. 2	NO. 3	NO. 4	NO. 5	NO. 6
Cement-Type	III	III	III	II	II	III
Bags/Cu. Yd.	10	4	3	3	2	3
Grinding sludge %	30	40	28	50	50	58
Coarse Aggregate %	70	30	36	25	25	
Fine Aggregate%		30	36	25	25	42*
CURE TIME	COMPRESSIVE STRENGTHS					
1 DAY		239		32		68
3 DAY	540					
4 DAY			776			
5 DAY	754	1014				203
7 DAY			861	155	40	356
14 DAY	1164	1353	1154	204	60	
28 DAY	1468	1671	1440	314	103	

*Fine aggregate consisted of grindings and surface median material for the groundwater ranged from 7.6 to 8.6. The pH of the soil was found to be close to 9; values are given in Table 5.

The prevalence of free water at the site and the possibility of groundwater contamination were major concerns. UDOT's roadway section design reflects the attention given to this matter. The solid particles were stabilized in a CTB; 6 in. of free-draining granular material was placed under and adjacent to the CTB as a capillary break; perforated drain pipe was placed in and a filter fabric was placed below the granular material to assist in stabilizing the subgrade; the CTB was prime coated top and sides; and finally a 15-mil-thick polyethylene sheet was placed over the top of the prime coat.

Construction of the treated base course proceeded in the following manner. After clearing, grubbing, and excavation to grade, a layer of filter fabric was put down followed by 6 in. of free-draining granular borrow. The CTB containing the grinding residue was laid down next. It consisted of, first, a 6-in. lift of the solids removed from the I-15 median and shoulders followed by a 6-in. lift of the sludge material from the drying beds. Portland cement was then placed over the grinding residue at a rate of 1 bag/yd^2. This equates approximately to a three-bag mix per cubic yard of soil-cement.

After application of the portland cement, a piece of heavy equipment, a recycler, was run through the lifts to mix the ingredients together. Water was added as needed. Most of the time, sufficient moisture was present in the grinding waste to meet the conditions of the special provisions, even after 4 months of drying in Utah's summer sun.

A road grader then proceeded to level the mix. Mechanical compaction to 96 lb/ft^3 dry density followed. After completion of the CTB, the remainder of the project (prime coat, polyethylene sheeting, granular borrow, untreated base course, bituminous surface course, and plant mix seal) was routine. Asphalt was laid down November 1990. (UDOT's specifications do not ordinarily permit asphalt placement after October 15 of any year, but because of the unusual nature of this project, allowances were made.) Traffic was on the finished roadway by December 1990.

TABLE 5 COMPARATIVE pH VALUES

1.)	Soil sample taken 6/25/90 from frontage road disposal project:	8.9
2.)	Water from drill hole #1, above defined site:	7.8
3.)	Water from drill hole #2, above defined site:	8.2
4.)	Water from drill hole #3, above defined site:	8.4
5.)	Water from drill hole #4, above defined site:	7.6
6.)	Water from drill hole #5, above defined site:	8.6
7.)	Polymer Modified Concrete (PMC) grindings taken from I-15:	12.1
8.)	PMC grindings + median material mixed 50/50:	11.3
9.)	Class F fly ash from the Navajo Power Plant near Page, Az.:	11.5
10.)	Ideal type III, High Early strength portland cement:	13.0

TABLE 6 DIRECT COSTS OF WASTE AND WASTEWATER DISPOSAL

Structural Section Modification Costs:	
Portland Cement Treated Base Course:	$70,000
6" Underdrain:	9,000
Filter Fabric	13,000
Polyethylene Sheeting	28,000
Prime Coat	2,000
Free Draining Granular Borrow	33,000
Sub-total	$155,000
Miscellaneous Costs:	
Hauling	162,000
UDOT Acid Treatment	60,000
Pumping Into Trucks	205,000
Standby Time During Shutdown	215,000
Bill From WWTP	9,500
Sub-total	$651,500
TOTAL	$806,500

TABLE 7 STRUCTURAL SECTION COST COMPARISON

Modified Section Costs:	
Section Modifications	$155,000
6" Granular Borrow (A-1-a)	18,000
12" Untreated Base Course	27,000
7.5 " Bituminous Surface Course	81,000
1" Plant Mix Seal Coat	14,000
	$295,000
Typical Section Without Modifications:	
27" Granular Borrow (A-2-4)	$83,000
12" Granular Borrow (A-1-a)	36,000
9" Untreated Base Course	20,250
7.5" Bituminous Surface Course	81,000
1" Plant Mix Seal Coat	14,000
	$234,250
Cost Difference:	$60,750

PROJECT COSTS

Table 6 gives the costs directly related to dealing with the waste and water disposal. Table 7 gives the additional cost generated by incorporating the solid waste into the roadway structural section.

CONCLUSIONS

To say that PCC is a major construction material in any urban environment is an understatement. The list of items constructed from PCC is extensive. When broken up or crushed, PCC becomes an alkali waste. Consequently, it has the potential to alter the environment; in our case, the pH of adjacent waters. This was UDOT's first experience of this nature. Activities conducted on a learning curve can be expensive, as was this project. Since then, ideas on how UDOT might handle a similar problem more effectively and less expensively have emerged.

One perceived scenario is as follows: During the grinding operation ready mix trucks will be on site and receive a specific amount of slurry discharge. They would then proceed to a batch plant and add calculated amounts of sand, rock, and cement to produce concrete meeting UDOT specifications for structures such as noise wall sections, Jersey concrete barriers, and so forth. This material would then be discharged into the appropriate forms, and the truck would drive back to the grinding operation to receive additional slurry. When finished, the UDOT will have a concrete product ready for use, rather than hundreds of thousands of gallons of wastewater and thousands of yards of solid waste to contend with.

Because of the high fines content of such waste, more than the usual amounts of portland cement are required to produce an acceptable concrete mix. Test batches have indicated around 12 bags/yd^3. This is expensive, but compared with treatment and disposal costs of an industrial waste, costs would be approximately one-half of those required to treat and dispose of the same quantity of waste material.

If soil and water conditions in Utah were more acid, as they are in other parts of the country, an alkali discharge might even be desirable. But most of Utah is desert, and millennia of leaching under hot, dry conditions are not conducive to acid soil or water conditions. Inevitably UDOT will encounter this problem again. Recent experience should provide a sound base from which to proceed.

ACKNOWLEDGMENTS

The authors express appreciation to DeLoy Dye and Joe Kammerer of UDOT for graciously providing most of the background information used in this paper.

REFERENCE

1. UDOT AADT Publication. 1989.

Publication of this paper sponsored by Committee on Mineral Aggregates.