CALCIUM CARBONATE PRECIPITATE FROM CRUSHED CONCRETE

R. W. Muethel

Research Laboratory Section
Materials and Technology Division
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Background

Inspections of geotextile-wrapped drainage system installations have revealed that geotextile filters can become coated with a calcium carbonate precipitate which has been found to occur when leachable calcium compounds are present in the drainage course aggregates. Laboratory tests for calcium carbonate precipitation have identified crushed portland cement concrete as an aggregate that will produce heavy calcium carbonate deposits when crushed to fine aggregate size. Tests for calcium carbonate precipitation have indicated that aggregates such as gravel, crushed stone, and blast furnace slag do not produce heavy calcium carbonate deposits when crushed to fine aggregate size (1).

This investigation was established to determine the comparative amount of calcium carbonate precipitate which would be produced by crushed concrete 5G open-graded drainage course, an aggregate which contains predominantly coarse sized particles. In addition to the crushed concrete, samples of gravel, crushed stone, and blast furnace slag were tested as control aggregates representing three major types of material available for drainage courses.

Test Samples

Samples of crushed concrete were obtained from three concrete recycling projects, I 96 at Ionia (IR 34043/24662A), I 96 West of Ionia (IR 34043/24663A), and I 94 at Marshall (IR 13082/24914A).

Control aggregate sample sources were: gravel (Source 19-24), crushed stone (Source 17-60), and blast furnace slag (Source 82-22).

Sample Preparation

The crushed concrete was graded into the following size fractions for separate testing and recombination into 5G composites for calcium carbonate precipitation tests.

Size Fraction	
Passing	Retained
1-1/2 in.	1 in.
1-in.	3/4 in.
3/4 in.	1/2 in.
1/2 in.	3/8 in.
3/8 in.	No. 4
No. 4	No. 200

The 5G composites were prepared according to the following gradation based on an average of 96 MDOT aggregate inspection samples.

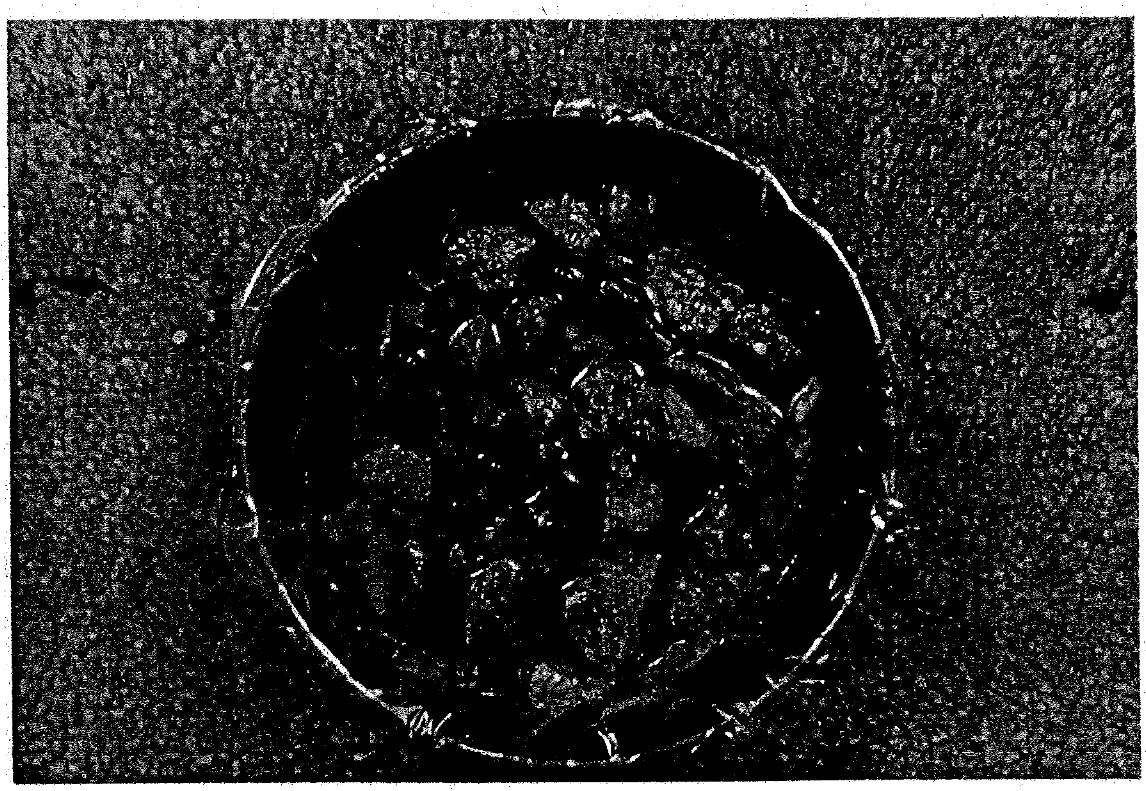

Figure 1. Crushed concrete, 5G gradation in a water leachate test for calcium carbonate precipitation. 0.4X magnification.

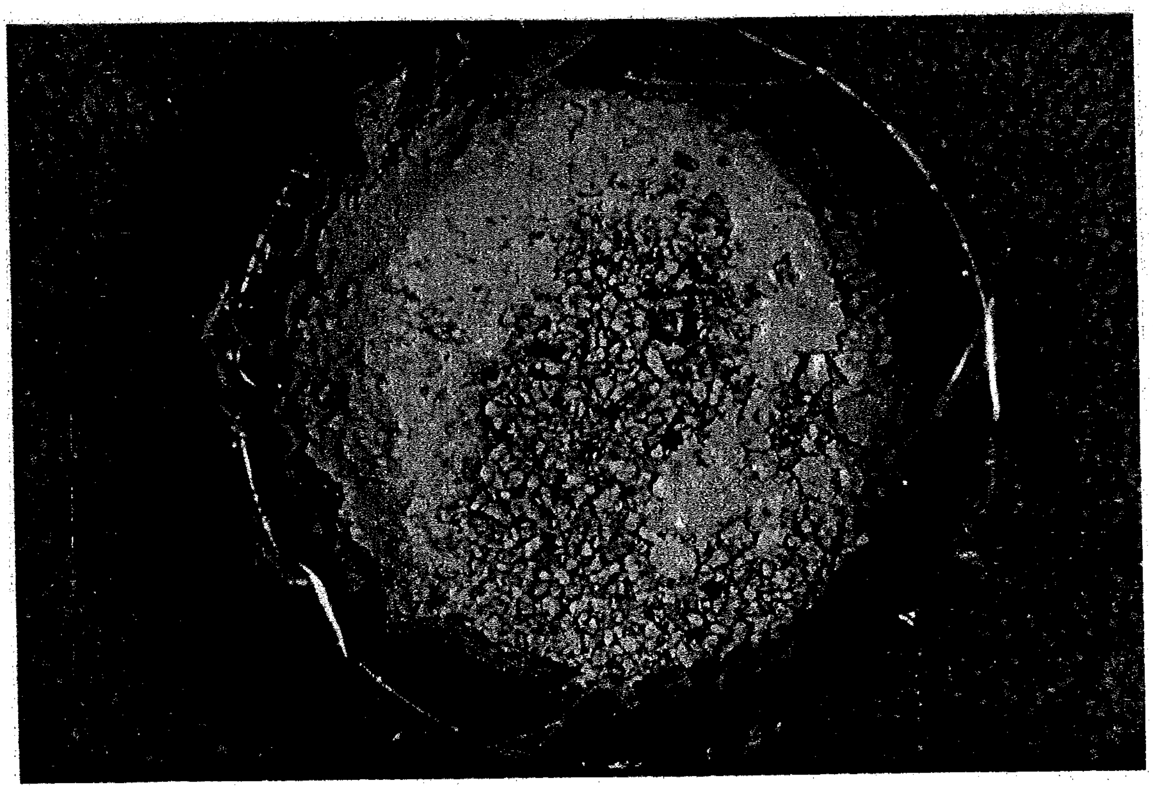

Figure 2. Calcium carbonate precipitate on crushed concrete fraction No. 4 to No. 200. 0.5X magnification.

Sieve Analysis		
Sieve Size	Retained, percent	Cumulative Passing, percent
1-1/2 in.	0.0	100.0
1/2 in.	82.8	17.2
No. 4	14.7	2.5
No. 200	1.6	0.9
P No. 200	0.9	
	100.0	

Quantities of approximately 500g were prepared for carbonate precipitation tests to be conducted on the individual aggregate size fractions and the 5G composites.

Carbonate Precipitation Test

The carbonate precipitation test used in this investigation was adapted from a test for carbonate precipitation developed in an earlier research project (1). The test involved shallow immersion of the aggregate in distilled water, producing a leachate from which leachable calcium compounds form calcium carbonate precipitation when reacted by atmospheric carbon dioxide.

Due to the larger particle sizes to be tested in this investigation, the test quantity of 100g stated in the test method was increased to 500g. Full-depth 8-in. diameter sieve pans were found to be suitable containers to accommodate the 500g aggregate samples immersed in distilled water, 1:1 by weight. Figure 1 shows a sample with 5G gradation, in a precipitation test.

For the purpose of this investigation the precipitation test was extended to three one-week soak periods which included drying and re-immersion with fresh distilled water to simulate the flushing action of several episodes of precipitation in a drainage system environment. Leachate pH measurements were obtained with Hydrion pH test strips and a PHEP electronic pH tester to measure a possible pH shift toward pH 7 (neutral). Such a reduction in alkalinity would indicate a decline in the leaching process and an associated decline in the potential for producing additional calcium carbonate precipitation.

At the end of each one-week soak period the samples of crushed concrete, with the exception of the No. 4 to No. 200 fractions, were removed from the leachate pans, rinsed, and oven-dried for weight-loss measurements. During the initial one-week soak periods, the No. 4 to No. 200 fractions of crushed concrete developed heavy calcium carbonate precipitates which could not be removed to permit further testing. The No. 4 to No. 200 fractions of the control aggregates did not develop calcium carbonate precipitates, and were tested for the entire three soak periods.

Figure 3. Calcium carbonate precipitate on crushed concrete fraction No. 4 to No. 200. 10X magnification.

Figure 4. Calcium carbonate incrustations and void linings formed as a precipitate on a partially immersed crushed concrete particle. 20X magnification.

FINDINGS

Carbonate Precipitates

The three crushed concrete samples produced similar results. In each set of tests the No. 4 to No. 200 leachate formed a heavy calcium carbonate surface film which solidified into a thin platy deposit composed of calcium carbonate crystal intergrowths (Figs. 2 and 3).

Calcium carbonate precipitation in the size fractions containing No. 4 and larger particles occurred as discrete calcite crystals on the leachate surface and as incrustations on partially immersed concrete particles. Calcite crystals were not evident on the fully submerged particles indicating that the leachable calcium compounds in solution react with carbonic acid formed at the liquid-air zone of contact, precipitating calcium carbonate. Microscopic examination of the crystals revealed pointed calcite spar intergrowths with individual crystal sizes measuring 0.2 mm and smaller.

The gravel and crushed stone control aggregates produced no calcium carbonate precipitation. The blast furnace slag control aggregate produced a small amount of calcium carbonate on the surfaces of the leachates indicating the presence of a small amount of unhydrated lime in the slag.

Figure 4 shows incrustations and void linings of calcium carbonate crystals on a crushed concrete aggregate particle which had been partially submerged in leachate.

Changes in Leachate pH

Portland cement concrete has a normally high pH (in excess of 11) which is incidentally beneficial for protection against rebar corrosion. The high alkalinity is mostly due to the presence of calcium hydroxide (portlandite), a major constituent of portland cement concrete (2). Crushing of the concrete would be expected to liberate increasing amounts of leachable calcium compounds with decreasing particle size and the resultant increased surface area available for reaction. Measurements of leachate pH indicated an increase in alkalinity with decrease in crushed concrete particle size. The 5G composites recorded intermediate pH values.

The pH of the unbuffered distilled water used for the leaching tests ranged from approximately 6 to 8. The leachate pH was noted to increase rapidly after immersion of the crushed concrete. The No. 4 to No. 200 leachates recorded pH values exceeding 11 (approaching caustic condition). The 3/8-in. to No. 4 leachates recorded pH values near 11 for the duration of the three soak periods, indicating that considerable material remained to produce additional calcium carbonate precipitation.

APPENDIX

Tables 1 through 12

TABLE 1
LEACHATE pH MEASUREMENTS
Crushed Concrete, I 96 Ionia

Time of Measurement	Sample Fraction						
	1 in.	3/4 in.	1/2 in.	5G	3/8 in.	No. 4	No. 200
After			1st Soak Period				
30 min.	6.4	6.8	7.0	7.2	7.2	7.6	10.5
1 day	10.0	10.3	10.6	10.7	10.9	10.8	11.3
7 days	10.1	10.7	11.0	11.0	10.7	11.1	11.8
After			(Leachate with Concrete Removed)				
2 days	7.9	8.3	8.2	10.9	8.2	11.1	11.4
3 days	8.0	8.1	8.1	10.5	8.1	11.1	dry
After			2nd Soak Period				
30 min.	9.7	9.9	10.1	9.8	10.2	10.2	—
1 day	9.8	10.3	10.5	10.1	10.9	11.1	—
3 days	9.8	10.2	10.5	10.4	11.1	11.3	—
7 days	9.4	10.3	10.5	10.4	10.5	11.1	—
After			3rd Soak Period				
30 min.	9.3	9.6	9.7	9.5	9.9	9.9	—
2 days	9.2	9.6	9.9	9.7	10.4	10.6	—
6 days	8.8	9.7	10.0	9.8	10.5	11.0	—
7 days	8.9	9.8	10.0	9.9	10.5	11.0	—

NOTE: The scale of alkalinity ranges from pH 14 (highly caustic) to pH 7 (neutral).

TABLE 2
LEACHATE pH MEASUREMENTS
Crushed Concrete, I 96 Ionia West

Time of Measurement	Sample Fraction						
	1 in.	3/4 in.	1/2 in.	5G	3/8 in.	No. 4	No. 200
After			1st Soak Period				
30 min.	9.9	10.1	10.1	10.6	10.1	10.1	11.4
3 days	10.2	10.7	10.9	—	11.2	11.2	11.5
10 days	9.3	9.7	10.8	—	10.9	—	dry
After			2nd Soak Period				
1 day	9.4	9.7	10.0	10.0	10.4	10.3	—
5 days	9.4	10.1	10.3	10.5	10.8	10.9	—
6 days	9.3	10.3	10.4	10.5	10.9	11.0	—
7 days	9.2	10.3	10.6	10.5	11.0	11.0	—
After			3rd Soak Period				
4 hrs.	9.1	9.2	9.3	9.3	9.4	9.4	—
3 days	8.6	8.6	9.0	9.2	9.9	10.1	—
7 days	8.5	8.7	9.3	9.6	10.2	10.4	—

NOTE: The scale of alkalinity ranges from pH 14 (highly caustic) to pH 7 (neutral).

TABLE 3
LEACHATE pH MEASUREMENTS
Crushed Concrete, I 94 Marshall

Time of Measurement	Sample Fraction						
	1 in.	3/4 in.	1/2 in.	5G	3/8 in.	No. 4	No. 200
After			1st Soak Period				
30 min.	10.7	10.8	10.9	10.8	11.0	11.1	11.1
4 days	10.3	11.0	11.1	10.9	11.2	11.3	11.3
6 days	10.0	10.9	11.0	10.9	11.1	11.3	11.3
7 days	9.8	10.9	11.0	10.9	11.1	11.3	dry
After			2nd Soak Period				
7 days	9.3	10.2	10.7	10.8	10.8	11.2	—
After			3rd Soak Period				
30 min.	9.4	9.4	9.6	9.6	9.7	9.9	—
1 day	9.3	9.8	10.2	10.2	10.4	11.0	—
4 days	9.2	9.6	10.6	10.1	10.5	11.2	—
7 days	9.3	9.6	10.7	10.4	10.7	11.2	—

NOTE: The scale of alkalinity ranges from pH 14 (highly caustic) to pH 7 (neutral).

TABLE 4
LEACHATE pH MEASUREMENTS
Control Gravel

Time of Measurement	Sample Fraction						
	1 in.	3/4 in.	1/2 in.	5G	3/8 in.	No. 4	No. 200
After			1st Soak Period				
30 min.	8.9	9.1	9.2	9.2	9.2	9.2	9.0
1 day	8.3	8.3	8.3	8.4	8.3	8.4	8.0
2 days	8.3	8.2	8.3	8.2	8.2	8.3	8.1
3 days	8.2	8.3	8.3	8.2	8.2	8.3	8.2
4 days	8.2	8.3	8.4	8.3	8.4	8.4	8.3
7 days	8.3	8.4	8.4	8.3	8.3	8.4	8.3
After			2nd Soak Period				
30 min.	9.0	9.1	9.3	9.4	9.4	9.3	9.0
1 day	8.5	8.4	8.4	8.5	8.3	8.3	8.2
4 days	8.5	8.4	8.4	8.4	8.3	8.4	8.3
7 days	8.5	8.4	8.4	8.4	8.3	8.4	8.3
After			3rd Soak Period				
1 day	8.4	8.4	8.5	8.4	8.5	8.5	8.3
2 days	8.3	8.3	8.3	8.3	8.3	8.4	8.3
3 days	8.3	8.3	8.3	8.3	8.3	8.3	8.3
6 days	8.3	8.3	8.3	8.3	8.3	8.3	8.3
7 days	8.3	8.3	8.4	8.3	8.4	8.4	8.4

TABLE 5
LEACHATE pH MEASUREMENTS
Control Crushed Stone

Time of Measurement	Sample Fraction						
	1 in.	3/4 in.	1/2 in.	5G	3/8 in.	No. 4	No. 200
After			1st Soak Period				
30 min.	a	9.1	9.2	9.4	9.3	9.3	9.3
1 day	a	8.2	8.2	8.4	8.3	8.3	8.3
2 days	a	8.2	8.2	8.3	8.2	8.2	8.2
3 days	a	8.2	8.2	8.3	8.2	8.2	8.2
4 days	a	8.3	8.3	8.4	8.3	8.3	8.2
7 days	a	8.3	8.3	8.3	8.3	8.3	8.2
After			2nd Soak Period				
30 min.	a	9.1	9.1	9.3	9.3	9.4	9.4
1 day	a	8.4	8.3	8.4	8.3	8.4	8.4
4 days	a	8.4	8.3	8.3	8.3	8.3	8.3
7 days	a	8.4	8.4	8.4	8.3	8.3	8.3
After			3rd Soak Period				
1 day	a	8.3	8.4	8.4	8.4	8.4	8.4
2 days	a	8.4	8.3	8.5	8.3	8.3	8.4
3 days	a	8.2	8.2	8.2	8.2	8.3	8.3
6 days	a	8.4	8.4	8.4	8.2	8.3	8.3
7 days	a	8.3	8.3	8.4	8.3	8.4	8.4

a. No 1-in. material available.

TABLE 6
LEACHATE pH MEASUREMENTS
Control Blast Furnace Slag

Time of Measurement	Sample Fraction						
	1 in.	3/4 in.	1/2 in.	5G	3/8 in.	No. 4	No. 200
After			1st Soak Period				
30 min.	10.4	10.5	10.3	10.2	10.2	10.0	10.0
1 day	10.7	10.7	10.9	10.7	10.8	10.7	10.6
2 days	10.0	10.1	10.4	10.3	10.4	10.2	10.3
3 days	9.9	9.9	10.2	10.2	10.2	10.0	10.0
4 days	9.8	9.7	10.0	10.0	9.9	9.8	9.8
7 days	9.7	9.5	9.7	9.9	9.7	9.7	9.9
After			2nd Soak Period				
30 min.	9.7	9.6	9.6	9.5	9.6	9.4	9.3
1 day	9.5	9.6	9.8	9.6	9.9	9.9	9.6
4 days	9.2	9.4	9.4	9.3	9.5	9.5	9.5
7 days	9.2	9.3	9.5	9.2	9.7	9.7	9.7
After			3rd Soak Period				
1 day	9.3	9.4	9.5	9.4	9.7	9.8	9.5
2 days	9.2	9.4	9.5	9.5	9.6	9.8	9.4
3 days	9.2	9.3	9.4	9.3	9.5	9.7	9.4
6 days	9.0	9.2	9.3	9.3	9.4	9.5	9.2
7 days	9.1	9.2	9.4	9.2	9.5	9.7	9.4

TABLE 7
WEIGHT LOSS MEASUREMENTS
Crushed Concrete, I 96 Ionia

Aggregate Size	Weight, g. Before Testing	Weight, g., After Testing		
		1st Soak	2nd Soak	3rd Soak
1-1/2 in. to 1 in.	497.9	497.0	b	b
1 in. to 3/4 in.	495.2	494.2	493.9	493.6
3/4 in. to 1/2 in.	496.3	495.4	495.2	495.0
5G Composite	491.6	491.7	489.5	489.3
1/2 in. to 3/8 in.	495.1	494.2	493.6	493.3
3/8 in. to No. 4	493.4	492.6	490.3	489.9
No. 4 to No. 200	482.7	a	a	a

a. Leachate soak test was terminated after first one-week soak period due to heavy calcium carbonate precipitate.

b. Sample removed for photo specimens.

TABLE 8
WEIGHT LOSS MEASUREMENTS
Crushed Concrete, I 96 Ionia West

Aggregate Size	Weight, g. Before Testing	Weight, g., After Testing		
		1st Soak	2nd Soak	3rd Soak
1-1/2 in. to 1 in.	496.0	495.9	496.1	496.3
1 in. to 3/4 in.	496.1	496.0	496.3	496.3
3/4 in. to 1/2 in.	495.2	494.9	495.0	495.0
5G Composite	492.1	488.0	488.2	488.5
1/2 in. to 3/8 in.	493.7	493.3	493.5	493.6
3/8 in. to No. 4	492.5	491.7	491.7	491.6
No. 4 to No. 200	490.6	a	a	a

a. Leachate soak test was terminated after first one-week soak period due to heavy calcium carbonate precipitate.

TABLE 9
WEIGHT LOSS MEASUREMENTS
Crushed Concrete, I 94 Marshall

Aggregate Size	Weight, g. Before Testing	Weight, g., After Testing		
		1st Soak	2nd Soak	3rd Soak
1-1/2 in. to 1 in.	494.2	494.2	494.4	494.2
1 in. to 3/4 in.	496.2	495.5	496.0	495.3
3/4 in. to 1/2 in.	496.2	495.4	495.4	494.9
5G Composite	493.0	486.8	486.1	485.5
1/2 in. to 3/8 in.	494.4	493.4	493.8	493.2
3/8 in. to No. 4	491.9	490.0	489.2	488.3
No. 4 to No. 200	492.2	a	a	a

a. Leachate soak test was terminated after first one-week soak period due to heavy calcium carbonate precipitate.

TABLE 10
WEIGHT LOSS MEASUREMENTS
Control Gravel

Aggregate Size	Weight, g. Before Testing	Weight, g., After Testing		
		1st Soak	2nd Soak	3rd Soak
1-1/2 in. to 1 in.	502.6	502.9	502.6	502.6
1 in. to 3/4 in.	508.4	508.5	508.3	508.3
3/4 in. to 1/2 in.	500.9	500.9	500.7	500.7
5G Composite	500.9	500.7	500.2	500.2
1/2 in. to 3/8 in.	500.0	500.1	499.9	499.9
3/8 in. to No. 4	500.1	500.1	500.1	499.9
No. 4 to No. 200	500.0	495.0	494.4	494.2

TABLE 11
WEIGHT LOSS MEASUREMENTS
Control Crushed Stone

Aggregate Size	Weight, g. Before Testing	Weight, g., After Testing		
		1st Soak	2nd Soak	3rd Soak
1-1/2 in. to 1 in.	a	a	a	a
1 in. to 3/4 in.	504.9	504.8	504.7	504.7
3/4 in. to 1/2 in.	502.6	502.4	502.3	502.3
5G Composite	500.0	495.4	495.2	495.2
1/2 in. to 3/8 in.	501.9	501.7	501.6	501.5
3/8 in. to No. 4	502.7	502.1	502.0	502.0
No. 4 to No. 200	503.0	496.3	496.0	495.9

a. No 1-inch material available.

TABLE 12
WEIGHT LOSS MEASUREMENTS
Control Blast Furnace Slag

Aggregate Size	Weight, g. Before Testing	Weight, g., After Testing		
		1st Soak	2nd Soak	3rd Soak
1-1/2 in. to 1 in.	503.6	502.9	502.6	502.5
1 in. to 3/4 in.	503.2	502.8	502.3	502.2
3/4 in. to 1/2 in.	503.0	501.9	501.5	501.5
5G Composite	500.0	494.7	494.3	494.4
1/2 in. to 3/8 in.	500.6	499.3	499.1	499.1
3/8 in. to No. 4	500.8	499.2	498.8	498.8
No. 4 to No. 200	500.4	489.3	488.7	488.5

NOTE: Small clusters of calcium carbonate crystals formed on the leachate surface during the first soak period. A trace of calcium carbonate formed during the second soak period. A few slag particles displayed traces of calcium sulfate deposition.