CTLGROUP

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ENVIRONMENTAL TESTING

The environmental testing program of Milliken Concrete Cloth™ is designed to evaluate the leachate coming off of the Concrete Cloth™ during its initial hydration state and after thorough hydration. The experimental program consisted of two stages: Stage 1) a controlled volume of water was sprayed on to a Concrete Cloth™ of known dimensions held at a defined slope at specific pressure. The water coming off of the cloth was collected and analyzed for its constituents. Stage 2) a large quantity of water was sprayed on to the hardened cloth to simulate run off on the cured cloth, again leachate was collected and analyzed for its constituents.

EXPERIMENTAL PROGRAM

Stage 1: Controlled volume of water spray on unhardened cloth

Two pieces of Concrete Cloth™ (Cloth A and Cloth B, 12" X 12"each) were extracted from the interior portion of a large roll (Type CC8). The edges of each cloth were sealed using commercially available silicon glue. To simulate the edge effect, the fourth edge of Cloth A and Cloth B was sealed in a way that had an opening of 0.75" and 1.5" respectively. However, due to the curling effect the open edge on the final (hydrated) product was 1" on Cloth A and 1.75" on Cloth B. To reduce the loss of cementitious material from the openings, the open edges of the cloths were reduced to 0.75" and 1.5" instead of 1.57" and 3.14" (proposed openings). After the silicon glue was set the cloths were positioned on the sloped surfaces that were prefabricated using plexiglass, the entire setup was then placed inside a spill safe container as shown in Figure 1. Using a custom built pressurized water tank (Figure 2), 1.25 gallons of DI water was sprayed on to the cloths while maintaining a flow pressure of 32 - 35 psi. Figure 3 illustrates the wetting setup of the Concrete Cloth™ . The quantity of water was selected based on the ASTM C1185 (Section: 15.4.2.1 Heat/Rain – Roof Structures). The standard states that an average rainfall in a period of one hour would yield 60 gallons of water over 48 Sq. ft. which is equal to 1.25 gallons over 1 Sq. ft. The pressure in the water tank was provided by connecting an air compressor to the tank. During spraying, care was taken to spray the water evenly across the entire surface area of the cloth. It took approximately 70 seconds to spray 1.25 gallons of de-ionized (DI) water under pressure (0.0178 gal/sec). Upon completion of wetting, water retained in the spill safe container was collected and stored for chemical analyses.

Stage 2: Three gallons of water spray on hardened cloth

In the second stage of leachate evaluation, a large quantity of water was sprayed on to the hardened cloth. After the wetting in Stage 1, the entire setup (slopes with Concrete Cloth™) was stored at 23 ^{o}C and 50% RH for 96 hours. Upon completion of the curing period (96 hours), 3 gallons of deionized (DI) water (max capacity of the tank) was sprayed on to the hardened Concrete Cloth™ while maintaining a flow pressure of 32 – 35 psi. Upon completion of spraying, the water retained in the spill safe container was collected and stored for chemical analyses.

Chemical analyses:

In Stage 1 the collected runoff from both the cloths was measured and vacuum filtered to separate the solids. Thus obtained solids were analyzed using X-ray fluorescence; results from the tests are listed in Table 2. In Stage 2 the collected runoff from both cloths was clear; no solids were observed during the vacuum filtration process. As a result X-ray fluorescence analysis of solids was not performed. The filtered water in both the stages was then spilt into two equal halves; one half of the water was used to evaluate the suspended solids (heating and XRF), while the other half was used to determine heavy metal content (by ICP). In performing the quantification of suspended solids a small quantity of DI water was heated to 100 deg. C. During this heating process water would evaporate leaving behind the suspended solids that could later be calculated as the weight average of total solids present in the solution. However, results obtained from the test showed 100% loss of weight during heating, indicating no suspended solids were present. X-ray fluorescence analysis of the liquid also did not show any major traces. In evaluating the heavy metal content in the wash water, the water was first acidified to meet the pH requirements of the test standard and then ICP measurements were carried out on the final solution. Results from the ICP test are listed in Table 4.

Figure 1 Sealed Concrete Cloth™ on sloped surface inside a spill safe container

Figure 2 Pressurized DI water tank

Figure 3 Wetting of Concrete Cloth™

RESULTS:

Table 1 DI water and separated solids quantification

	Stage 1 (12"X12")		Stage 2 (12"X12")	
Cloth edge opening	0.75" (Sample A)	1.5" (Sample B)	0.75" (Sample C)	1.5" (Sample D)
Total amount of water sprayed (gallons)	1.25	1.25	3	3
Total amount of water collected (gallons)	0.79	0.82	simulating runoff- not quantified	simulating runoff - not quantified
Separated solids (grams)	12.384	8.232	<0.001	<0.001

- The amount of cementitious material collected from Sample B was slightly less than the amount collected from Sample A. There are two possible hypotheses to explain this variation: 1) handling of Concrete Cloth™ during the setup process, or 2) it could be due to local packing density caused during manufacturing of the Concrete Cloth™ .

Table 2 XRF analyses of the original cementitious material and the separated solids obtained in Stage 1 (12"X12")

Analyte	Original Sample (cementitious powder extracted from Concrete Cloth™)	Stage 1	
		Sample A	Sample B
SiO_2	4.24	4.23	4.24
Al_2O_3	39.43	29.19	28.63
Fe_2O_3	15.58	14.70	15.61
CaO	36.85	27.38	27.25
MgO	0.60	0.56	0.58
SO_3	0.13	0.11	0.12
Na_2O	0.07	0.04	0.05
K_2O	0.09	0.03	0.03
TiO_2	1.80	1.68	1.78
P_2O_5	0.15	0.15	0.16
Mn_2O_3	0.27	0.25	0.27
SrO	0.02	0.02	0.02
Cr_2O_3	0.17	0.11	0.11
ZnO	0.03	0.03	0.03
L.O.I. (950°C)	0.95	21.29	20.67
Total	100.37	99.76	99.55

Loss on ignition is the percentage weight loss experienced by hydrated cement upon ignition (~950 deg. C.). During the ignition process carbon, water and other volatiles associated with the material are lost which are reported as percentage weight loss. In the case of Sample A and Sample B, LOI was performed on hydrated material. Ignition of hydrated material causes loss of bonded water, which is why the LOI for Sample A and Sample B is high.

Table 3 Quantification of dissolved solids

Stage	DI water sample	Wt. of crucible (gms)	Wt. of crucible plus sample (gms)	Wt. after heating (gms)	Total percent dissolved solids
Stage 1	Sample A	15.1504	16.0428	15.1500	<0.045
	Sample B	15.1467	16.1041	15.1461	<0.063
Stage 2	Sample C	15.1820	16.2136	15.1791	<0.282
	Sample D	15.1239	16.0609	15.1213	<0.278

The total dissolved solids percentage is calculated as percent variability in crucible weight to sample weight; e.g. for Sample A ((15.1504-15.1500)/(16.0428-15.1504))*100.

Table 4 Heavy metal content leaching from the original cementitious material and in the wash water during hydration and after hydration

Analyte	RCRA TCLP Max. conc. (mg/L)	Original Cementitious Material (not exposed to water) (mg/L)	Stage 1 (water sprayed on 1 Sq. ft. of cloth)		Stage 2 (water sprayed on 1 Sq. ft. of hardened cloth)		Base run with DI water (mg/L)	ICP detection limit
			Sample A (mg/L)	Sample B (mg/L)	Sample C (mg/L)	Sample D (mg/L)		
Antimony (Sb)	1	0.04	0.06	0.06	BDL	BDL	BDL	<0.01
Arsenic (As)	5	0.36	0.06	0.06	BDL	BDL	BDL	<0.04
Barium (Ba)	100	0.089	0.22	0.20	0.12	0.14	0.24	---
Beryllium (Be)	0.007	0.003	BDL	BDL	BDL	BDL	BDL	<0.0007
Cadmium (Cd)	1	0.007	BDL	BDL	BDL	BDL	BDL	<0.001
Chromium (Cr)	5	0.028	0.006	0.005	BDL	BDL	BDL	<0.001
Lead (Pb)	5	BDL	BDL	BDL	BDL	BDL	BDL	<0.01
Mercury (Hg)	0.2	BDL	BDL	BDL	BDL	BDL	BDL	<0.001
Nickel (Ni)	70	0.033	BDL	BDL	BDL	BDL	BDL	<0.002
Selenium (Se)	1	BDL	BDL	BDL	BDL	BDL	BDL	<0.06
Silver (Ag)	5	BDL	BDL	BDL	BDL	BDL	BDL	<0.0003
Thallium (Tl)	7	BDL	BDL	BDL	BDL	BDL	BDL	<0.02
pH (scale 0 - 14)		11.1	11.11	11	9.21	8.86	7.32	

Further descriptions of key items from Table 4:

- BDL indicates "below detection level".
- pH values listed are the actual pH obtained for each solution before performing ICP tests on them. The values reported are observed when 1.25 gallons (Stage 1) and 3 gallons (Stage 2) of DI water are sprayed.
- ICP test on base run wash water indicates the presence of Barium, most probably from the test setup (tub, facet head, etc...). Thus Barium detected during Stage 1 and Stage 2 studies should be noted as background.
- The Environmental Protection Agency's (EPA) Resource Conservation and Recovery Act (RCRA) is designed to protect human health and environment, which lists maximum concentrations of contaminants for toxicity characteristic. The values listed under RCRA TCLP column represent those values listed by EPA.
- To evaluate the contaminants coming from DI water and/or the test setup, ICP test was conducted on wash water of the entire test setup (without the Concrete Cloth™). Results obtained from the test are reported in the base run column.

OBSERVATIONS AND RESULTS INTERPRETATION:

1. In Stage 1, during the initial hydration of the Concrete Cloth™ , an average of 10 grams of cementitious material is lost from the Concrete Cloth™ per one square foot surface area with ~1.4" open edge. In Stage 2 there were no filtered solids indicating no loss of material after hydration even with the presence of an open edge.
2. X-ray analysis of the lost solids show a similar chemistry as the original cementitious material extracted from the cloth before hydration.
3. In both the stages dissolved solids were less than 0.3 Wt. % of the water after filtration. This percentage can likely be reduced by using a larger volume of liquid.
4. ICP analyses of wash water in both the stages indicate that in most cases the concentration of heavy metals leaching during and after hydration of the Concrete Cloth™ is less than the amounts leaching from the original cementitious material (The original powder sample extracted from the cloth was evaluated in an earlier investigation (March 27, 2012) and is included under column three in Table 4, Original Cementitious Material. The exceptions to this are Antimony and Barium, which show higher concentrations in Stage 1 than in the original powder material. In Stage 2, after hydration, concentrations drop to very low levels. The concentration measured for the listed heavy metals is far below the EPA limits.
5. In the case of Chromium (an important element related to environmental considerations), the concentration leaching from the powdered cementitious material appears to be more than that leaching from the cloth during its hydration and after it is cured. Also, Chromium concentration appears to be marginally higher during the hydration than in cured condition. However, the concentration of Chromium leaching (for 12" X 12" Concrete Cloth™) during and after hydration is far below the EPA limits.
6. In the case of Antimony, Arsenic, and Chromium, the concentration of the individual element appears to decrease from Stage 1 to Stage 2. This appears to indicate that the hardened Concrete Cloth™ is able to arrest the leachability of these elements by locking them in the hardened cementitious binder.
7. The RCRA TCLP procedures would generally take a solid waste material and make it into pieces of approximately 3/8" square. Thus the TCLP testing conducted using the cementitious powder matrix can be described as a "worst case" scenario; these values were below RCRA limits. The subsequent evaluation of run off is also an extreme case, where some of the powder is dislodged or washed away during the strong spray; these TCLP values are also below RCRA limits.
8. The pH values reported in Table 4 are the values measured on the collected runoff when specific volumes of water (1.25 gallons for Stage 1 and 3 gallons for Stage 2) are sprayed on to one square foot surface area of unhydrated and hydrated Concrete Cloth™. The pH values measured in the field may be different to those reported above, as dilution will eventually neutralize the pH content. For example, when 1.25 gallons of a liquid with pH 11 is diluted by adding 53.75 gallons of pH neutral water to make a 55 gallons drum the resulting pH of the final liquid in the drum would be 9.4. Similarliy, if a 3 gallon pH 9 liquid is diluted to make a 55 gallon drum the final pH of the liquid in the drum would be 7.7.