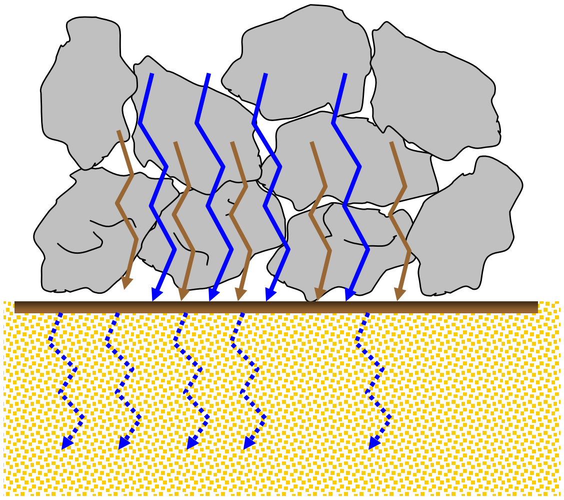
INVESTIGATION REGARDING THE ISSUE OF FINES IN AGGREGATE USED FOR SOIL ABSORPTION SYSTEMS

PROJECT NUMBER 01-05/319

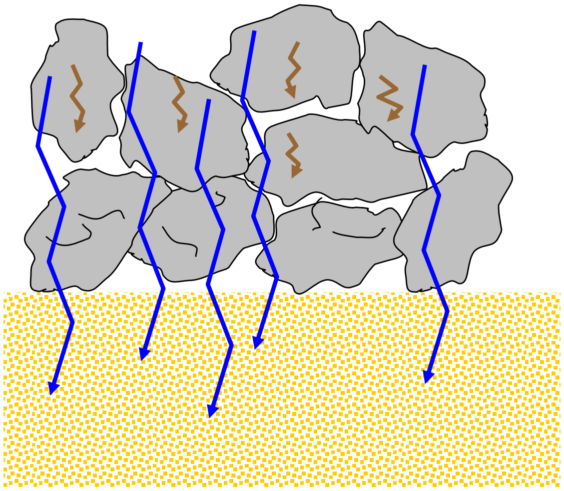
CONDUCTED 2004-2006

Is fine material on aggregate entrained to the soil/media interface resulting in a flow barrier and premature SAS failure?



OR

Does fine material for the most part remain attached to the aggregate and not pose a significant problem to flow in the SAS ?



PREPARED BY
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PREPARED FOR
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
BUREAU OF RESOURCE PROTECTION
AND
THE ENVIRONMENTAL PROTECTION AGENCY REGION I

DECEMBER, 2006

INVESTIGATION REGARDING THE ISSUE OF FINES IN AGGREGATE USED FOR SOIL ABSORPTION SYSTEMS

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MASSACHUSETTS EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
Robert W. Golledge, Secretary

DEPARTMENT OF ENVIRONMENTAL PROTECTION
Arleen O’Donnell, Acting Commissioner

Executive Summary

Commonwealth of Massachusetts Regulations pertaining to the installation of onsite septic systems require that base aggregate used for leaching structures be “free of iron, fines and dust in place.” Absent of any field testing procedure for aggregate, it is difficult for contractors or inspectors to reasonably ensure adherence to the intent of the regulation. The purpose of the present study was to determine whether any rapid field tests for aggregate quality were in use in other jurisdictions and to research, in a preliminary way, factors for consideration in the assessment of aggregate in the field.

This study made use of the extensive network of practitioners in the field of onsite wastewater and the regulator community available through the Environmental Protection Agency internet listserve. Three separate inquiries were made. The survey verified that, although the problem of “dirty stone” (referring to what is perceived as aggregate with excessive fine material) is universally recognized, there is no consensus regarding reasonable methods for determining quality of aggregate with the exception of ASTM tests, which might impose unreasonable delays during septic system installation. In addition there is no universal agreement as to what amount of fine material, using standard laboratory tests such as American Standards of Testing Materials Method C177, would constitute an unacceptable level.

To research some of the issues relative to aggregate quality and its impact on soil absorption system performance, field test cells were constructed and test were performed on aggregate of differing quality relative to fine material content. Test cell conditions were optimized to favor the entrainment of fine material from the aggregate surface to the soil interface, and thus represent the worst possible conditions. The results of field tests were compared with results from subsamples tested using the ASTM Method C177.

The results of laboratory tests indicated that the range of fine material in all cells including controls was 0.1-0.5% fine material by weight. No significant correlation between percent fines and percolation rate was observed. Of note is the fact that the unwashed aggregate, which we believe would have been universally rejected for use for septic systems, performed better than a number of double washed test aggregates including the “clean” control in some cases. These results suggest that subjective means of evaluation of aggregate may be inadequate as a tool to ensure compliance with requirements of the Massachusetts regulation in similar situations. As a substitute for subjective tests performed at the time of aggregate placement, we recommend that a requirement for periodic random sampling of aggregate supply be considered (perhaps twice per year). These results suggest that up to 0.5% fine material, when the receiving soil is a predominantly sand, can be tolerated with little impact to system performance. The reader is cautioned to consider that the present study was performed using loamy sand as a soil interface and a limited (0.1-0.5% fines by weight) quality of aggregate. There are no data to suggest that these results extrapolate to finer-grained base soils or higher percentages of fine material.

Literature reviewed revealed little understanding of the quantitative effects of fines in coarse aggregate used for soil absorption systems. While some authors comment and speculate on the impact of fines during initial placement of the soil absorption system, none comment on the possible attenuating effect the biological component of wastewater disposal on the entrainment of fines to the soil interface. Conversely, some allied literature reviewed suggests that wastewater biota could serve to stabilize and hold fines in place on the coarse aggregate. Additional research is necessary in order to extrapolate these results to finer-grained receiving soil and different hardness coarse aggregate.

This project was funded by the Massachusetts Department of Environmental Protection with funds from the United States Environmental Protection Agency under a Section 319 competitive grant. The contents of this report do not necessarily reflect the views or policies of the departments mentioned nor does the mention of any product trade name constitute and endorsement.

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Figures and Tables

Introduction

The standard onsite septic system in the Commonwealth of Massachusetts is comprised of a septic tank, a means of conveying the septic tank effluent away from the septic tank toward the soil absorption system, and the soil absorption system itself (variously called leachfield, leaching bed, leaching facility or “leaking bed”). The septic tank serves both as a settling area for solid material suspended in wastewater and as a biological anaerobic digester of household waste. In gravity-operated septic systems, a distribution box receives septic tank effluent and, when properly leveled and adjusted, diverts equal portions of effluent to the various sections of the soil absorption system (SAS). Alternately, septic tank effluent may be dispersed to the SAS using pressurized pipes. The SAS itself is comprised of conveyance and void features that facilitate the dispersal of effluent to the soil interface.

A traditional transition feature between septic tank effluent dispersal pipes or structures and the soil is variously-sized stone aggregate (¾” to 1½ “). Stone aggregate provides structural support for the excavation, void storage space for effluent, and substrate for bacteria and other organisms beneficial to the stabilization of wastewater. Massachusetts regulations posit that in order to be effective, aggregate used in SAS must be free of fine material as these regulations state in 310 CMR 15.247(1): “Base aggregate for leaching structures shall be provided from below the elevation of the crown of the distribution line(s) to the bottom elevation of the soil absorption system and shall consist of double washed stone ranging from ¾ to 1½ inches in diameter and shall be **free of iron, fines and dust in place**” (emphasis added).

Readers Please Note
Although “fines” are not defined, it is generally understood that fines are materials smaller than 75 microns (0.075 mm) and that will pass through a #200 Alternate Sieve in the process of performing American Standards of Testing Materials Method C177 (ASTM 1998).

The reason for limiting fine material in aggregate is presumably to prevent the migration of fines to the soil interface where they might occlude pore space and impede the percolation of wastewater. Amerson et. al. (1991) and May (1996) suggested that fines migrating downward are potentially a greater problem in newly constructed septic systems than compaction by falling gravel. White and West (2003) reported that the presence of 0.5% fines in aggregate can result in a 60% reduction in the hydraulic conductivity beneath the SAS. This project resulted from discussions with health agents regarding the inability to properly assess the quality of stone aggregate in the field. Some assessment of aggregate quality must be made during the construction process for soil absorption systems to verify compliance with the above-referenced regulation. Presently, this assessment is based on an often-subjective qualitative assessment. Many health officials presently rely on the integrity of the installer to purchase double-washed stone and use prudent measures to ensure its quality prior to placement (store and transport it properly).

The present project foremost attempted to determine whether there were any standardized rapid field tests in use that were able to evaluate the quality of the stone. The obvious challenge to this first objective is the lack of any standard for comparison. If the words “free of” in the above cited regulation are taken in their full meaning, *no* fine material should be tolerated in aggregate used in SAS. This investigator has not observed acceptable aggregate using this standard in over 20 years of observations and hundreds of septic system installations in Barnstable County, Massachusetts.

Given that the “no fines” criterion is unrealistic, the second objective of this project was to further the understanding of the impact of fine materials in aggregates on the performance of SAS, with the goal of using information gathered to develop realistic guidelines for health agents and system inspectors charged with evaluating the quality of aggregate.

Study Approach

To determine whether there were any rapid field tests in use that are presently being used and have proven helpful, we surveyed a number of practitioners and researchers. It was obvious from the beginning of our survey that although the problem is universally recognized, there are no rapid field methods for *quantitatively* assessing the quality of stone aggregate relative to fine materials in the field. In addition to making inquiries to many state officials, we posted a nationwide search for information on the EPA list serve (Onsite/decentralized wastewater management issues decentralized@lists.epa.gov) on two occasions. A special list serve only available to regulators was also queried.

In an attempt to assess the present situation in Barnstable County relative to fines in aggregate and to further assess how the present situation potentially impacts the performance of septic systems, we designed the following field study.

First, a 16’ x 20’ test cell area was prepared at the Massachusetts Alternative Septic System Test Center. The test area was created by excavating the sand out of an existing 40’ x 20’ x ~10 ft deep lined cell and replacing the top 24” with loamy sand (<15% clay fraction). The loamy sand was placed in 6” lifts and compacted. Following compaction of the uppermost lift of loamy sand, percolation tests were performed in two locations. The results indicated that the percolation rate of the loamy sand was approximately five minutes per inch. This area served as the basal infiltration area for our study.

Following the preparation of the basal area, 24 individual 48” deep cylindrical test cells were the placed in a 4 unit by 6 unit array on top of the loamy sand (Figure 1). Loamy sand was then used to fill in around the individual test cells to an elevation of approximately 24 inches. A low-pressure distribution system was constructed such that each cell was served by a single 3/8” discharge orifice oriented to discharge at the 12 o’clock position. Each orifice hole was fitted with an orifice shield to protect it from blockage. A layer of filter fabric was placed over the aggregate in each cell to prevent the entry of fine material and dust from above. Between and around the cells was top dressed with leaf mulch to prevent freezing. The test area is variously depicted in Figures 1 -3.

Aggregates for testing were obtained from five suppliers that serve Barnstable and surrounding counties. Lots were tested in triplicate; that is each load of aggregate was partitioned among three test cells. For one of the suppliers located in Barnstable County, aggregate was procured on two different occasions in order to assess the variability in their “double-washed” aggregate between warm and cold conditions. In addition to the test aggregate, we employed two controls. The first control was repeatedly hand washed with a pressurized hose at close range and loaded into the triplicate cells using a washed back hoe bucket. This aggregate load was first deposited on an impervious tarp for washing and to prevent contamination with fine material during the loading process. A second set of control cells was filled with non-washed “driveway stone” obtained from Lawrence Lynch, Inc. in Falmouth, Massachusetts. This facility does not sell washed stone, so there was no possibility of having delivered washed stone aggregate. A sample of all aggregate tested was sent to a certified laboratory for a determination of percent fines using ASTM Method C177.

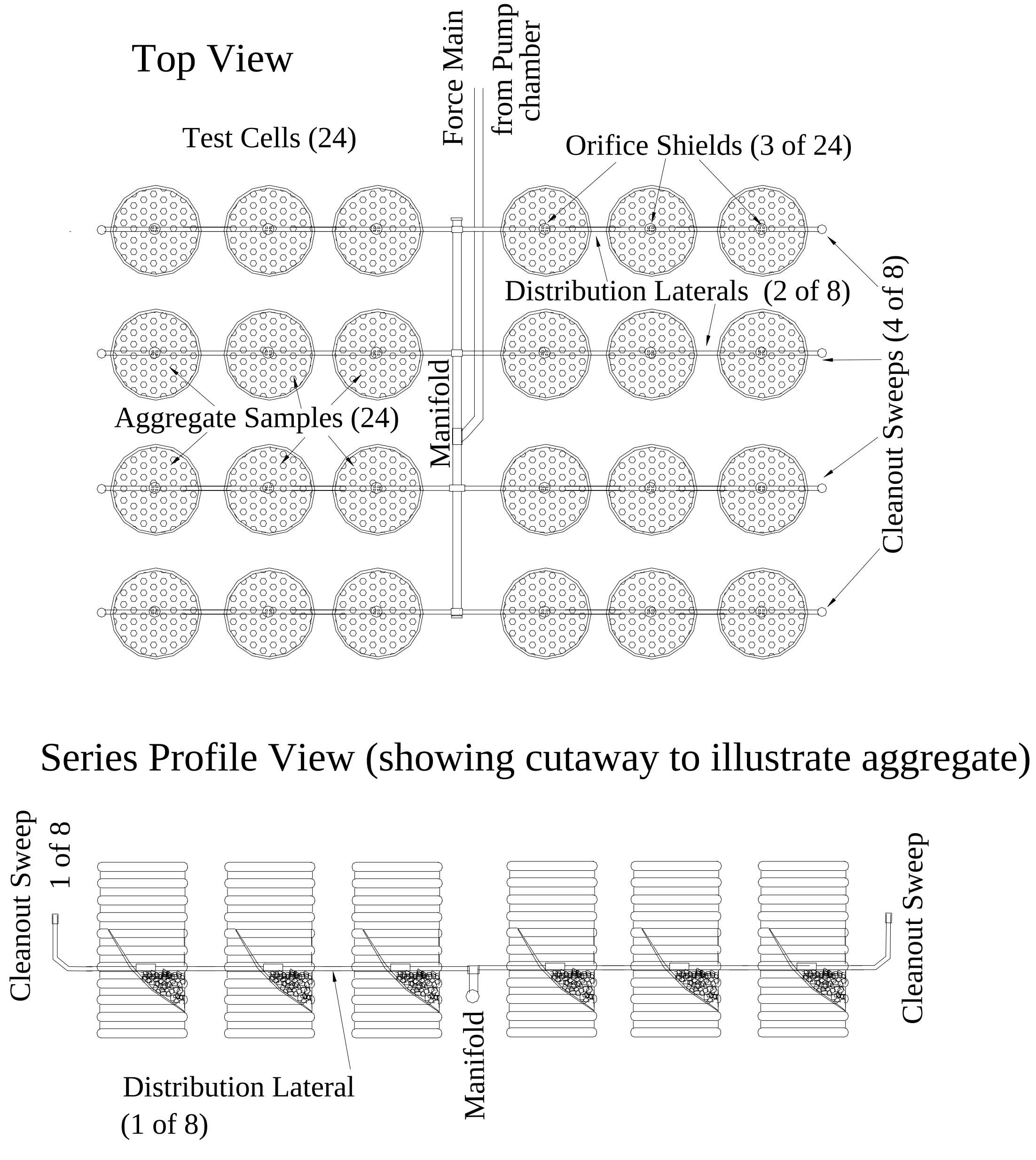


Figure 1. Schemata showing the plan and side view of aggregate test cells located at the Massachusetts Alternative Septic System Test Center.

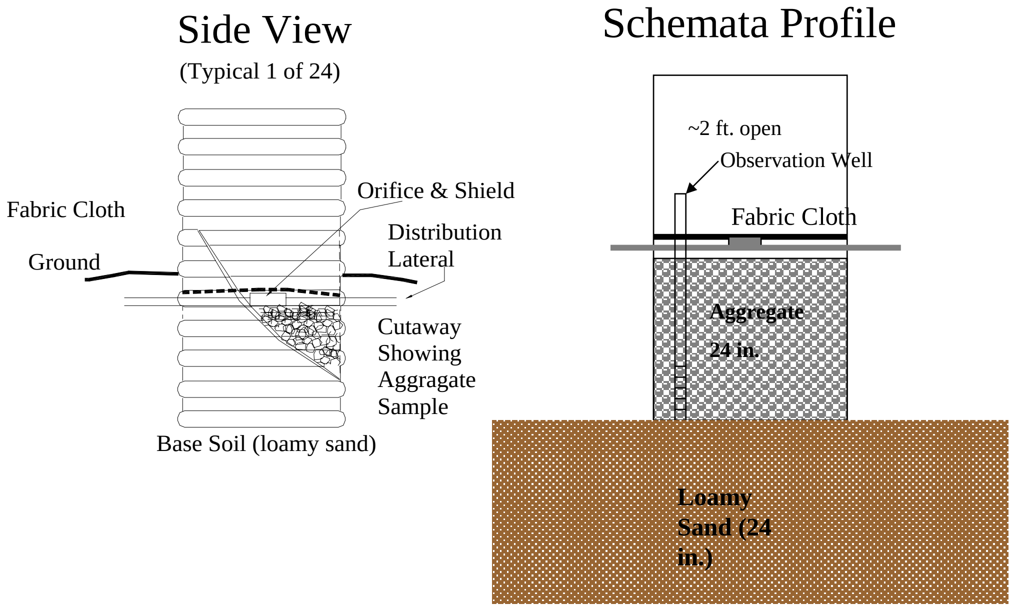


Figure 2. Illustration and profile schemata of a single test cell used for testing stone aggregate samples.

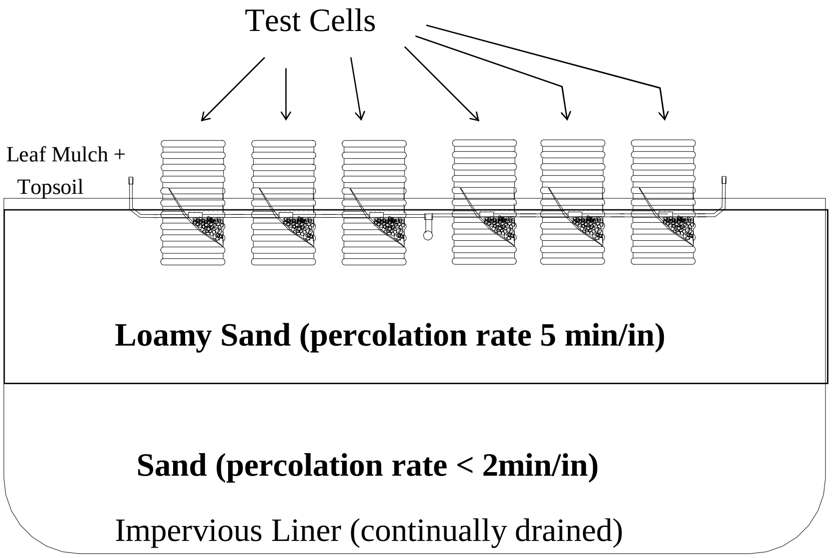
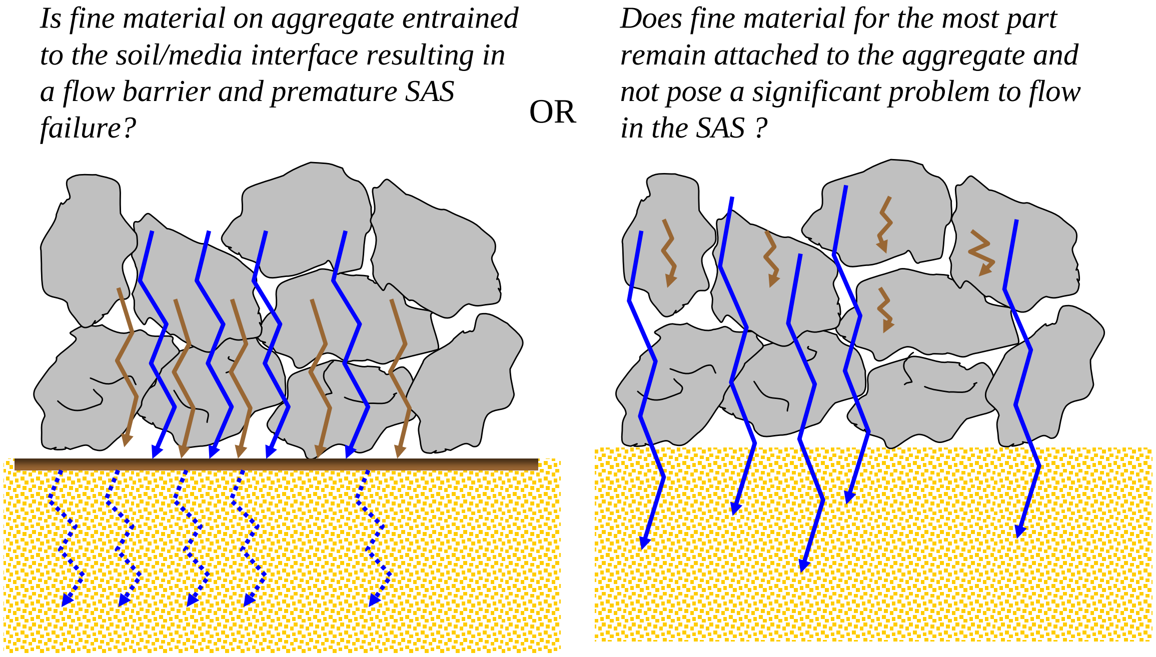


Figure 3. Illustration of test cell series showing position relative to receiving soils and impervious liner.

This investigation endeavored to determine the impact of the fine materials observed in each test cell. To accomplish this, each test cell was flooded daily for sixty days with 11.8 gal of septic tank effluent (enough to fill and empty cell to a depth of six inches or 25% of the effective depth) in a single dose of duration less than 20 minutes. In addition, on the day of tests, each cell was flooded to a depth of 24 inches with clean water dispensed in a single dose of duration less than five minutes. These conditions were meant to simulate extreme stress regarding the migration of fine material from the surface of the aggregate to the soil interface. Once at the soil interface, the postulated detriment to the SAS is the clogging of pores and the prevention of percolation. Figure 4 illustrates the basic question.



Is fine material on aggregate entrained to the soil/media interface resulting in a flow barrier and premature SAS failure?

OR

Does fine material for the most part remain attached to the aggregate and not pose a significant problem to flow in the SAS ?

Figure 4. Illustration of the tested question as to the fate of fine materials associated with soil absorption system aggregate.

To measure differences in the percolation rate (the rate at which applied liquid passes through the aggregate-soil interface), we constructed a device that allowed for rapid visualization of liquid depth inside the aggregate cell. A ½” PVC pipe, having marks corresponding to 24”, 21”, 18”, 15” and 12” and attached to a buoyant bottle served as the device. To initiate the test, the cell was filled to a 24” depth. As the water percolated (dropping the float-measuring device), a timer was started when the depth of liquid in the cell is 21”. Time measurements were recorded every 3”, however the total time to percolate 9’ of liquid (from the 21”-12” level) was used for comparisons. Figure 5. illustrates the testing procedure sequence.

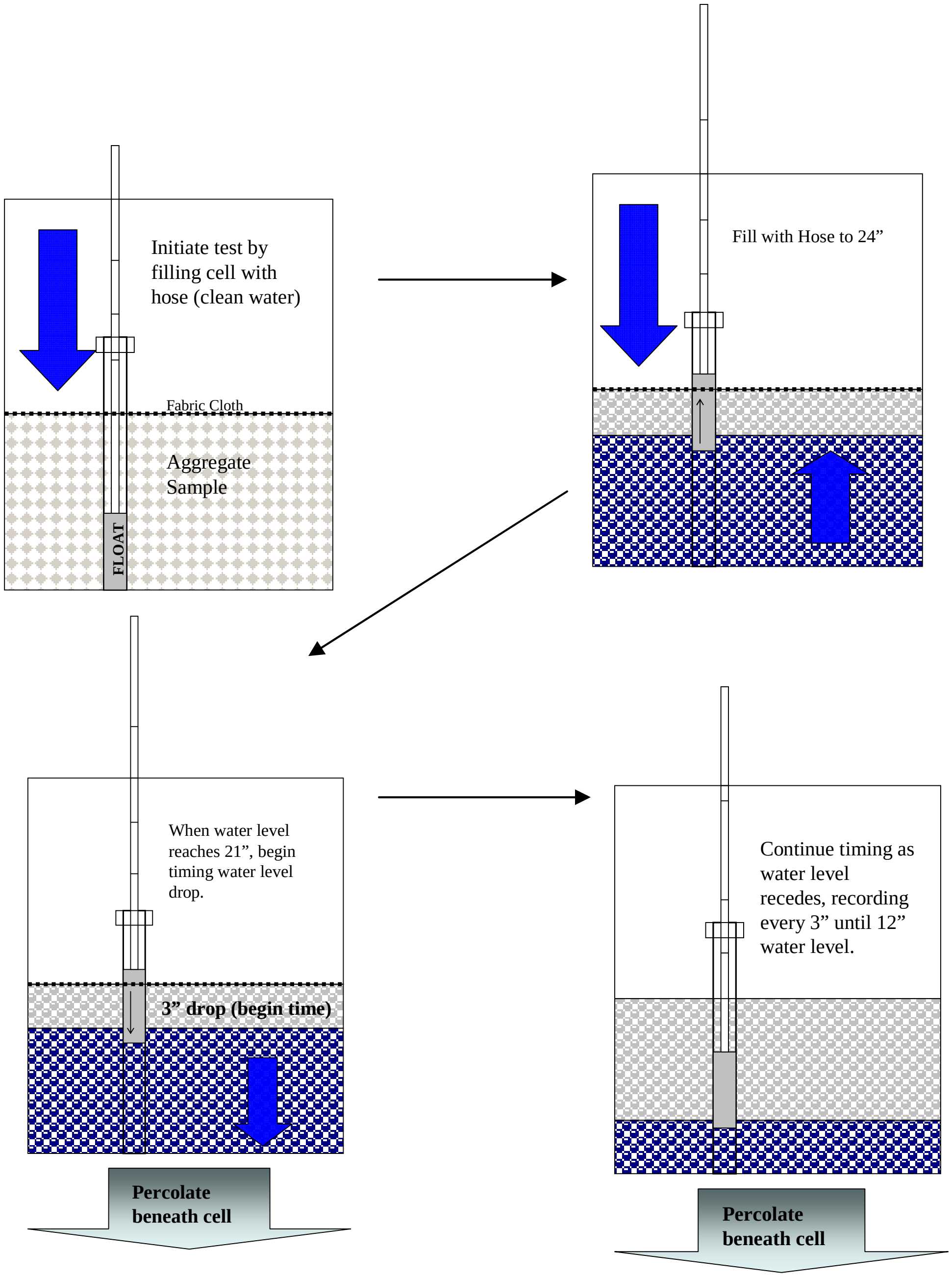


Figure 5. Representation of percolation test conducted on test aggregate at the Massachusetts Alternative Septic System Test Center.

"Percolation tests"[1] were performed in the described manner on three dates (September 7, September 11, and October 4, 2006). Following these three tests, we conducted a final series of percolation tests on November 7, 2006. In these latter tests, the filter fabric was removed from the top of the aggregate and the stone was washed from the top under a garden hose nozzle pressure. We attempted to wash the entire exposed surface area in an attempt to simulate the worst (albeit artificial) condition. Since we again filled the cells to the 24 inch depth, this last condition would simulate a torrential downpour on an exposed SAS. In reality, this condition would only occur during construction of the system, prior to backfilling.

Note
The reader is cautioned not to compare the percolation tests performed on the test cells with the percolation tests described in 310 CMR 15.000 (TITLE 5). Percolation tests performed on the aggregate cells did not allow for lateral movement of effluent across the sidewall area (since this is restricted by the cell wall). In addition, the vertical head of regulation percolation test is prescribed as nine inches. The vertical head in aggregate cell tests exceeded 12 inches. Finally the bottom area of the test cells is four times that of a standard perc test hole.

Results

Percolation test data and laboratory analyses for the 24 cells are presented in Table 1. The data indicate little impact of fines on the percolation rate of the underlying soils. To make the comparison, the average percolation rate of the "clean" controls was used as an index and entered into the following equation:

$$CC/\ TC$$

Where CC is the mean percolation rate of the clean controls on the test date and TC is the percolation rate of the aggregate cell being tested.

If CC/ TC < 1 then the percolation time of TC is longer than that of CC and hence the test cell demonstrates a ***slower*** percolation rate (in minutes/inch) than the control mean..
If CCM/TC > 1 then the percolation time of TCP is shorter than that of CCM and hence the test cell demonstrates a ***faster*** percolation rate (in minutes/inch).
If CCM/TC = 1 then the percolation time of TCP is the same as CCM and hence the test cell demonstrates the ***same*** percolation rate (in minutes/inch).

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[1] Percolation tests is in quotes here to indicate this study's distinction between the procedure described in 310 CMR 15.105 and the tests performed as a part of this study.

	Percolation Rate in Minutes/Inch Minutes:Seconds				
	9/7/2006	9/11/2006	10/4/2006	11/7/2006	Laboratory Analyses - Percent Fines
Clean Control	1:18	2:08	0:48	3:07	0.2
Clean Control	1:21	2:17	1:06	2:55	
Clean Control	0:30	0:51	0:28	1:23	
PA1	1:28	0:56	0:45	2:02	0.1
PA1	0:17	0:29	0:21	0:46	
PA1	0:17	0:31	0:22	0:54	
CC1	0:36	0:53	0:36	1:23	0.2
CC1	1:09	1:25	0:53	2:14	
CC1	0:44	0:49	0:36	1:21	
CC2	3:09	2:46	3:13	4:07	0.2
CC2	1:28	5:29	8:21	4:26	
CC2	0:38	0:56	0:53	1:29	
LL	0:58	1:19	0:50	2:27	0.3
LL	0:57	1:23	1:09	2:27	
LL	1:13	1:57	1:49	2:42	
PA2	1:10	1:19	0:57	1:38	0.1
PA2	1:51	2:10	0:59	1:43	
PA2	3:10	3:28	3:28	9:30	
PL	1:12	1:21	1:06	2:13	0.4
PL	3:25	3:11	2:18	9:25	
PL	3:33	3:51	3:24	6:41	
BY	1:46	2:38	1:58	5:34	0.5
BY	0:58	1:26	0:55	2:14	
BY	1:36	2:03	2:06	5:55	

Table 1. Results of percolation tests performed on aggregate samples procured from various suppliers in southeastern Massachusetts. Fines analyses were conducted by Briggs Engineering, Rockland, Massachusetts.

Test cell indices comparisons are depicted in Figures 6-9. The raw data indicate considerable variability among replicates of each aggregate, which limited statistical comparisons between aggregate loads.

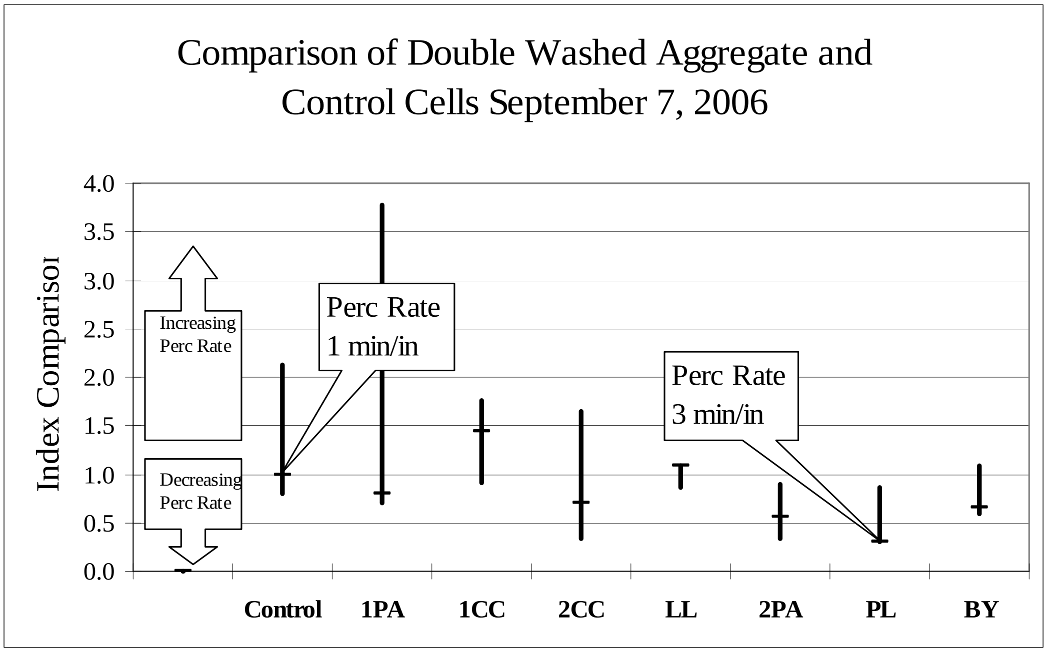

Figure 6. Comparison of the control aggregate and aggregate from selected suppliers in southeastern Massachusetts. Selected percolation rates are provided for examples. Minimum, mid and maximum values for each cell plotted. Tests performed on September 7, 2006.

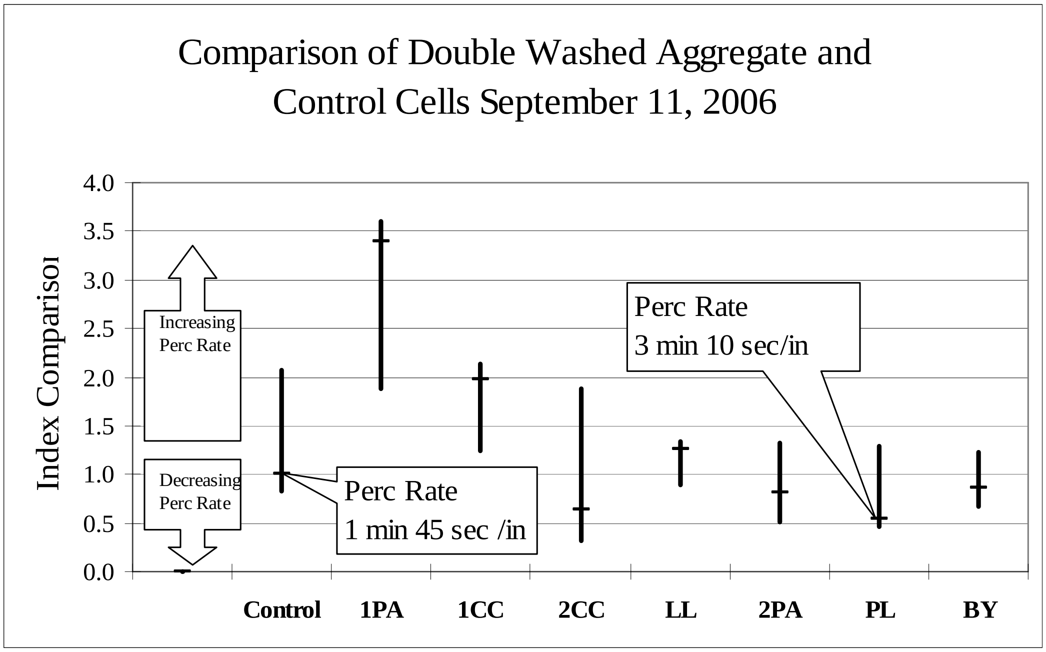

Figure 7. Comparison of the control aggregate and aggregate from selected suppliers in southeastern Massachusetts. Selected percolation rates are provided for examples. Minimum, mid and maximum values for each cell plotted. Tests were performed on September 11, 2006.

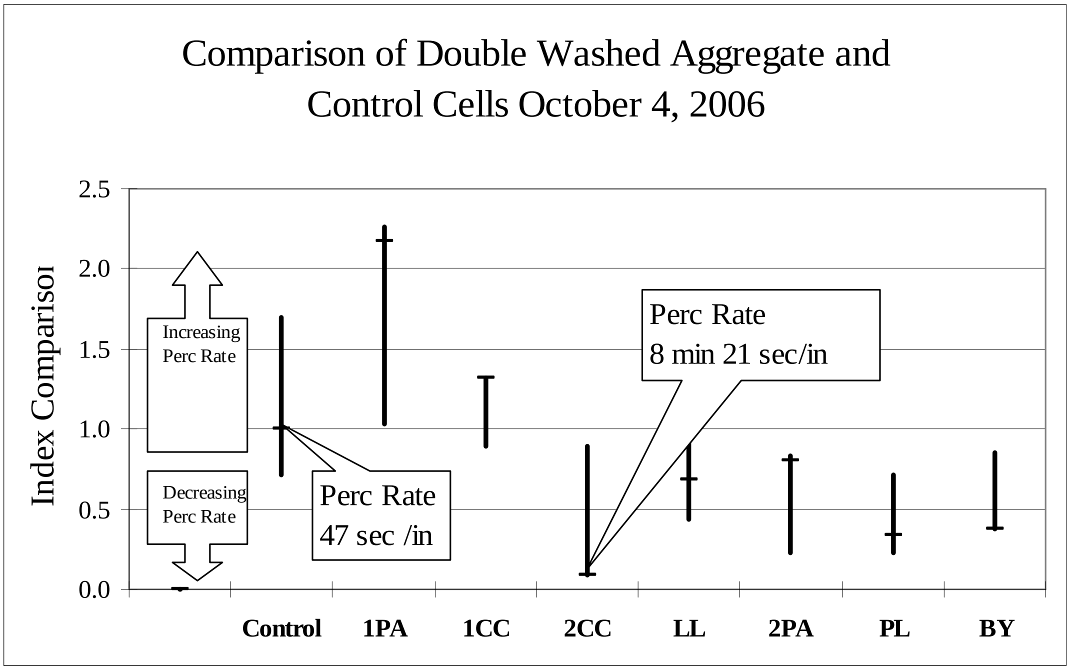

Figure 8. Comparison of the control aggregate and aggregate from selected suppliers in southeastern Massachusetts. Selected percolation rates are provided for examples. Minimum, mid and maximum values for each cell plotted. Tests were performed on October 4, 2006.

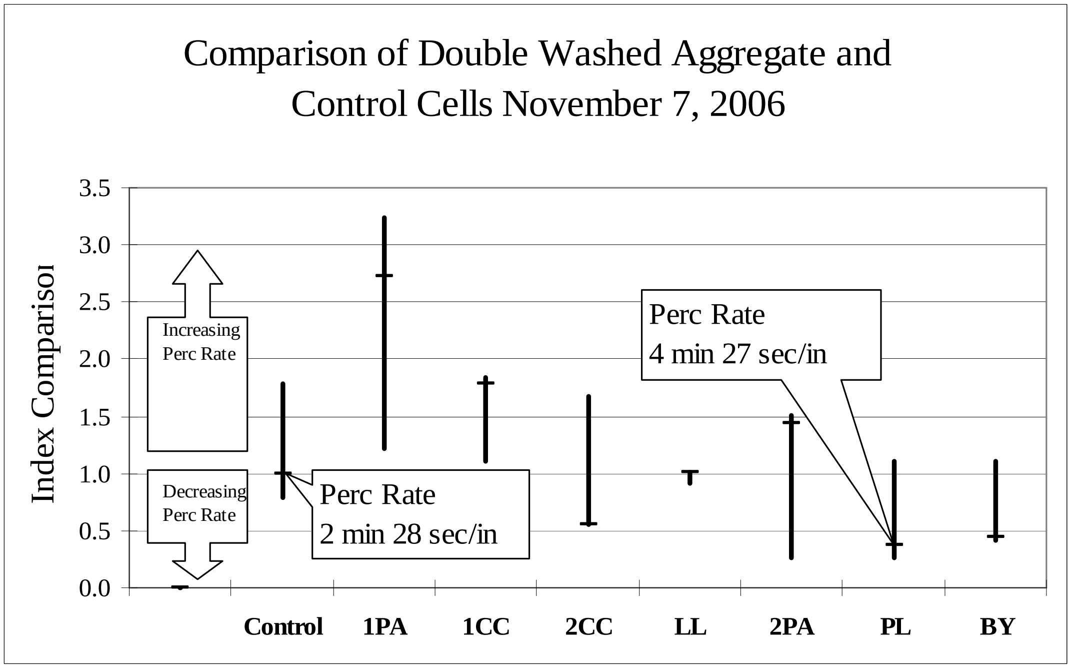

Figure 9. Comparison of the control aggregate and aggregate from selected suppliers in southeastern Massachusetts. Selected percolation rates are provided for examples. Minimum, mid and maximum values for each cell plotted. Tests were performed on November 7, 2006.

Discussion

Prior to discussing these results, it is useful to again restate that the conditions under which the aggregate cells were tested were meant to accelerate the natural processes generally theorized as responsible for dislodging fines from the aggregate. By daily applying septic tank effluent having enough volume to fill the voids in the aggregate to a depth of over six inches (>15 cm) for sixty days, conditions exceeded the allowed loading rate of the underlying soil by over five times[2]. In addition, under "normal" conditions, the effluent would be distributed over a 24 hour period. In this series of tests, dosing occurred over 20 minutes, a factor that likely exposed more aggregate surface area to higher surface liquid velocities, favoring the dislodgement of fines. Finally, it is unlikely that under any normal conditions the effluent level front oscillates across the aggregate surfaces to the extent caused during this study (a possible six inch rise within 15-20 minutes). This frequent oscillation provides more opportunity to dislodge fine materials which then fall downward as the effluent levels recede downward toward the soil interface. In summary, all controllable aspects of effluent were dramatically enhanced to facilitate the washing of fines from the aggregate surfaces and facilitate their passage to the soil interface. If it is theorized that stone aggregate, of the quality tested, contains fine materials at levels that can impair SAS function, we believe we would see evidence of this fact in the tests performed.

This study presented a number of unexpected and perplexing results. An inspection of the data revealed that, with few exceptions, one of each of the triplicate samples exhibited a consistently slower or faster percolation rate than the other two replicates across all test dates by a factor of 1.5 or greater (Table 2). Since most of the known factors relative to aggregate cell construction and installation are believed to have been controlled, we examined whether there was a pattern to the occurrence of the faster replicates within the array of test cells that might be attributable to uneven distribution of effluent during the sixty day period of wastewater flow. While the even distribution of effluent within the array was confirmed at the initiation of the study, it was not verified on a regular basis. Pressure distribution networks are subject to periodic biases in distribution patterns caused by plugging orifices.

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[2] 310 CMR 15.242: LTAR - Effluent Loading Rates specifies a loading rate of 0.74 gpd/sq.ft. or 3 cm for this soil.

Aggregate Designation	Replicate Paired Percolation Rates / Index (Faster or Slower Rate)			
	9/7/2006	9/11/2006	10/4/2006	11/7/2006
Clean Control(1)	2.64	2.53	1.72	2.25
Clean Control(2)	2.74	2.70	2.38	2.12
Clean Control(3)	**Consistently Faster Percolation Than Replicates**			
PA1(1)	**Consistently Slower Percolation Than Replicates**			
PA1(2)	5.06	1.92	2.19	2.66
PA1(3)	5.30	1.81	2.10	2.24
CC1(1)	1.92	1.60	1.46	1.62
CC1(2)	**Consistently Slower Percolation Than Replicates**			
CC1(3)	1.57	1.73	1.49	1.67
CC2(1)	4.96	2.96	3.66	2.78
CC2(2)	2.32	5.88	9.49	2.99
CC2(2)	**Consistently Faster Percolation Than Replicates**			
LL(1)	1.26	1.49	2.17	1.10
LL(2)	1.27	1.40	1.58	1.11
LL(2)	**Consistently Slower Percolation Than Replicates**			
PA2(1)	2.72	2.62	3.68	5.80
PA2(2)	1.71	1.60	3.54	5.55
PA2(3)	**Consistently Slower Percolation Than Replicates**			
PL(1)	**Consistently Faster Percolation Than Replicates**			
PL(2)	2.83	2.35	2.09	4.24
PL(3)	2.94	2.84	3.09	3.01
BY(1)	1.83	1.84	2.13	2.50
BY(2)	**Consistently Faster Percolation Than Replicates**			
BY(3)	1.65	1.44	2.29	2.66

Table 2. Replicate comparison made by dividing outlying replicate performance by remaining two replicate percolation rates or visa versa to obtain factor difference in percolation rates. Aggregate designation format is LOAD NAME (REPLICATE NUMBER). The index replicate and its performance relative to remaining two replicates is purposely in boldface.

A plugged orifice in any one cell would expect to result in overall faster percolation rates at that cell during our tests, since wastewater-induced effects during the sixty days of flooding would have been reduced. An inspection of the pattern of faster percolation-rate cells (Figure 10) revealed no obvious trend with the possible exception that the cells served by the distal end of the eastern distribution laterals all exhibited the faster percolation test replicates.

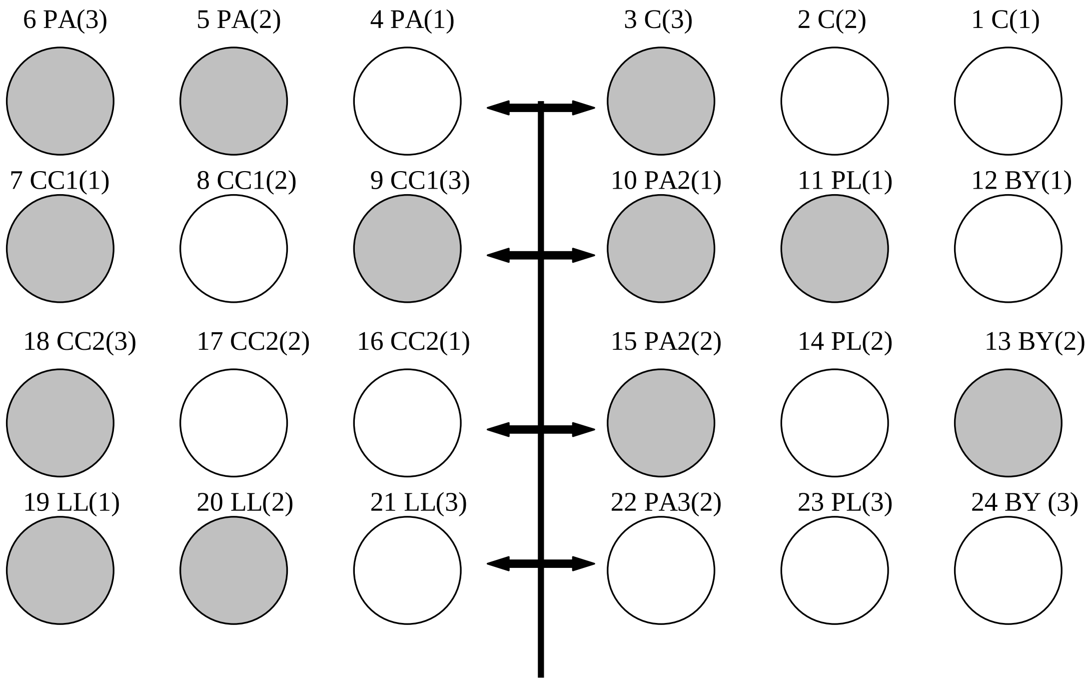

Figure 10. Schemata of aggregate test cell array. Shaded circles indicate cells exhibiting the faster percolation rates. Aggregate designation format: AGGREGATE LOAD (REPLICATE).

Accordingly, no definitive conclusion to explain the single replicate in each load that exhibited performance differences in the order exceeding 1.5.

Perhaps the most perplexing result observed was the comparative performance of the unwashed aggregate (LL). This aggregate would have been universally refused as appropriate for SAS use, yet in the first two percolation tests, its performance, as indicated by a faster percolation rate, exceeded that of the control cells and at least three of the other “double-washed” aggregate samples. In addition, this set of replicate cells did not exhibit the phenomena described in the previous paragraph to the same extent as all other replicate sets. Of the seven comparisons where the outlying replicates did not differ from the performance of the other two in their respective sets by a factor exceeding 1.50, four of those were observed in the unwashed aggregate series. These data suggest that the unknown variable(s) that induced intra-replicate variability was at least dampened by the features of unwashed stone.

When the percolation rates for the first three test dates are plotted against the determined percent fines from one to five percent, no significant trend is exhibited (Figure 11)

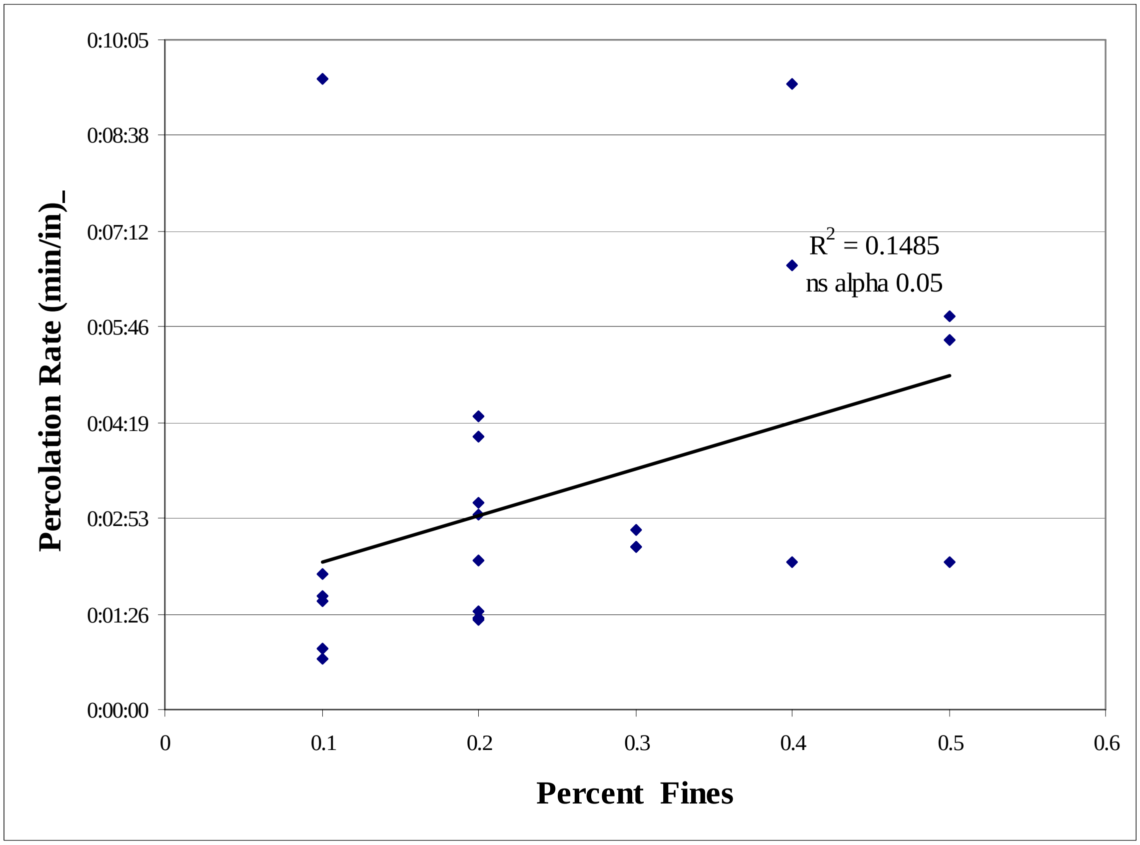

Figure 11. Average percolation rate (min/in) taken from tests on three dates plotted against the percent fines for aggregate samples procured from selected sources in southeastern Massachusetts. Correlation is not significant at the .05 level of significance.

The data collectively suggest that under the conditions imposed before and during the first three tests, one generally could not predict the percolation based on the percent fines (for the range 0.1-0.5 percent fines).

Following these tests, more severe conditions were imposed on all cells by washing the entire exposed surface of the cells with a volume of water necessary to fill the cell to the 24” depth. Although the correlation between percolation rate and percent fines appears better for these data, the relationship is still not significant at the 0.05 level of probability (Figure 12).

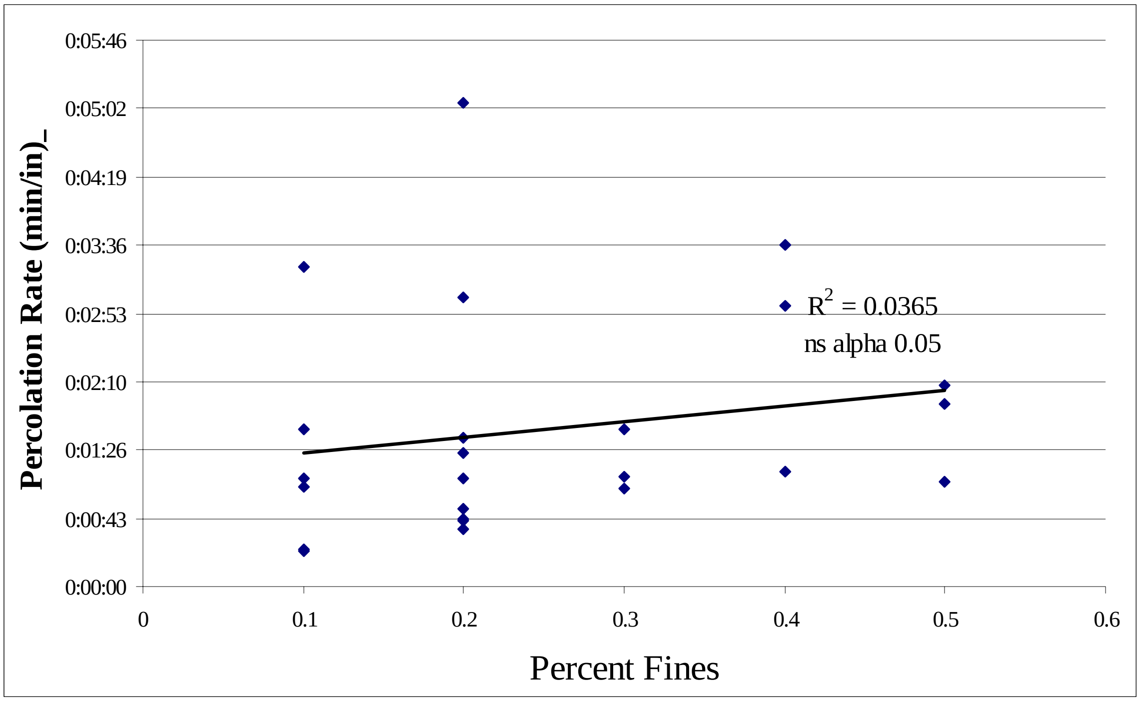

Figure 12. Average percolation rate (min/in) taken from tests on November 7, 2006 plotted against the percent fines for aggregate samples procured from selected sources in southeastern Massachusetts. Correlation is not significant at the .05 level of significance.

This final “stress” testing of the cells begins to reveal the impact that migrating fines might have on percolation rates in loamy sand. Eighteen of the cells exhibited percolation times twice that of the pre-stress date. Only one cell exhibited faster percolation rates following the stress. It appears that under extreme conditions, fine material can be entrained to the soil interface and reduce the percolation ability of the underlying soil. However it is unlikely that these extreme conditions would occur under any normal circumstances.

The present study suggests that presence of fine materials on SAS aggregate up to 0.5 percent by weight had little impact on the performance of the SAS with underlying conditions of sand or loamy sand. These results contradict those of White and West (2003) who theorized that the presence of just 0.5% fines reduced the effective conductivity of the underlying soil by 60%. These authors contend that “Over a short period of time, the fines wash from the gravel and settle to the bottom of the trench.” Similarly, rates of 1-4% of gravel fines by weight was found by Amerson et. al. (1991) to reduce infiltration rates by 35-65%.

We believe that while some of the fines in our test cells may have washed to the bottom of the trench, it is likely that some and perhaps the majority of the fine material stayed adhered to the aggregate and may not have migrated to the soil interface. Despite our artificial acceleration of the physical processes that would dislodge fines and entrain them toward the soil interface of the SAS, no significant reduction in effluent percolation across the soil interface was observed in the test cells. Even under the most extreme conditions of removing the fabric cloth and directing a pressure spray over the exposed surface of the aggregate, the acceptance rate of the soil interface remained well above the Long Term Acceptance Rate (LTAR), specified for this soil type (0.74 gal/day/sq ft). In addition to this quantitative result, we also observed the persistence of fine material adhered to the aggregate despite numerous high pressure washings of our control cell aggregate prior to placement in the test cell. From this observation, we conclude that the physical shearing and entrainment forces acting on the fine material when the aggregate is in place (which would be far below the forces imposed during repeated turning and pressure washing), would not be adequate to dislodge a significant percentage of the fine material.

Although considerable research by Siegrist et. al. (2004) and others has been conducted regarding reduced effective infiltrative area caused when using aggregate, there has been little quantitative research specifically on the aspect of fines from aggregate and their impact on underlying soil acceptance rates. Most of the research has focused on the direct effect of aggregate itself and its placement on the infiltrative surface architecture. There are least two feasible explanations for the apparent lack of fines migration from the surface of the stone aggregate to the soil interface. Foremost, we previously noted the difficulty in dislodging silt to clay sized particles (< 75 microns) using pressure spray. Under normal conditions, wastewater is directed over the SAS aggregate at much lower velocities. Consequently, we believe that due to the electrostatic attractive forces of the silt or clay, there is increased resistance to the shearing/entrainment forces of the percolating effluent on the fine material that is in close association with the larger aggregate. An additional consideration in this aspect is the actual percentage of aggregate surface area actually exposed to meaningful flow of percolate. In gravity fed systems, 5/8” holes disperse the effluent along the effluent distribution lateral in much localized areas that actually occupy a very small percentage (<1%) of the available surface area. This area of exposure is even less in pressure distribution systems due to the lower number of discharge holes. Thus, the vast majority of aggregate is precluded from experiencing downward flowing percolate except in situations where ponding across the entire SAS is receding. During this later situation, the velocities are much reduced (<1”/minute).

The second possible factor restricting the downward entrainment of fine material from the surface of the aggregate to the soil interface may relate to bacterial and fungal growth induced by the wastewater. Evidence for this mechanism comes from a variety of disciplines. Quaresma1 et. al. (2004), while investigating factors lending to the stability of sediments subject to shear forces in marine environments found that bacterially colonized areas were twice as stable as those areas treated with an antibiotic. Tisdall (1991 and 1994) reviewed the role of hyphae from fungi in stabilizing soil by forming macroaggregates (>0.25 mm) from microaggregates (<0.25 mm), and implicated extracellular polysaccharides in the process of stabilization. Kohler et. al. (2006) noted increased aggregate stability in soil inoculated with a fungus and bacterium. Some authors suggest that the presence of organic matter alone may encourage aggregate[3] stability (Lynch and Elliot, 1983).

These studies collectively suggest that biological activity or the result of biological activity in the environment within the coarse aggregate of a SAS may cause fine particles to adhere to each other and to the coarse aggregate itself. Thus a combination of physical attractive forces, adhesive forces of bacteriological and fungal exudates such as polysaccharides, entanglement with fungal hyphae, and chemical binding may prevent the entrainment of fines to the soil interface.

Conclusions and Recommendations

The present study is limited by the fact that coarse aggregate used ranged in percentage of fine materials from 0.1-0.5%. In addition, the study does not allow for the extrapolation of these results beyond situations where the underlying soil is loamy sand (sand with less than 15% clay fraction). Data presented indicate that aggregate containing 0.5% or less fines by weight, determined by performing an American Standards of Testing Materials Method C177 (ASTM 1998) test, will have little impact on the performance of the SAS when used under these conditions. Since no quick field test was found that enabled assessment of the aggregate, and our own subjective assessment would have failed to predict the actual percentage of fines, inspectors in the field should consider an alternate option to ensure the quality of aggregate. As a supplement to subjective qualitative assessments of aggregate quality at the time of placement,

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[3] For purpose of clarification, the reader should understand that the word “aggregate” in these cited studies refers to the coalescence of fine particles, such as clay or silt, into larger structures with varying size and stability. This is in contrast to the use of the word in context of the coarse aggregate used in soil absorption systems.

we recommend that suppliers of aggregate be required to test their aggregate biannually and that acceptable levels of 0.5% fines or less be required. The means by which aggregate samples should be taken for purposes of demonstrating compliance could be determined by convening a committee of regulators, industry suppliers, inspectors and installers. It is clear that the “no fines” requirement of the Massachusetts septic system regulations needs clarification and definition. Our data and observations suggest that the total absence of fines in coarse aggregate is likely not achievable, nor is it probably necessary. However some guidance and verification of aggregate quality should be instituted to ensure the proper response to the intent of the regulation.

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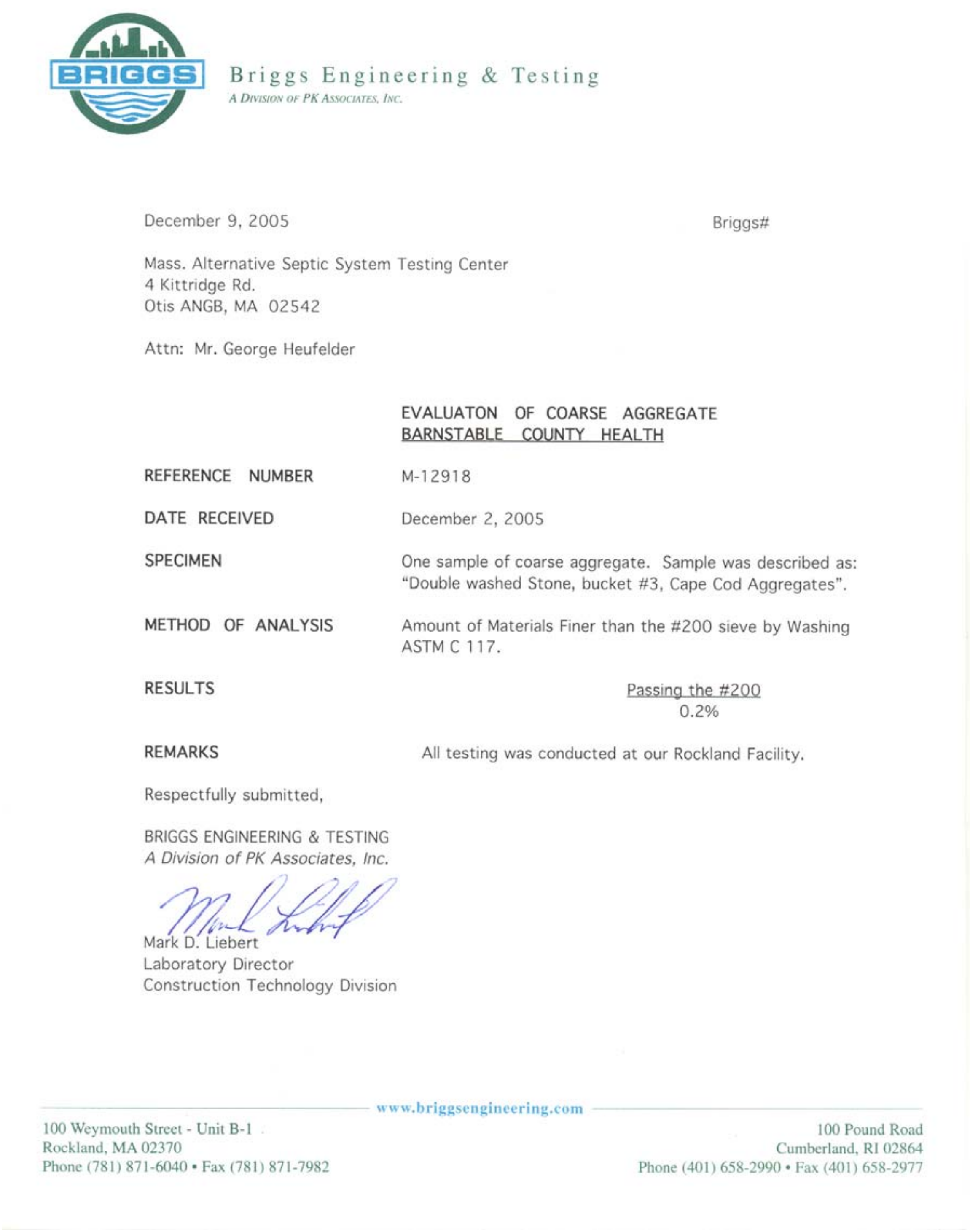
Appendix 1

Results of ASTM C 117 Testing on Coarse Stone Aggregate

(Copies of Laboratory Reports)



Briggs Engineering & Testing
A Division of PK Associates, Inc.

December 9, 2005

Briggs#

Mass. Alternative Septic System Testing Center
4 Kittridge Rd.
Otis ANGB, MA 02542

Attn: Mr. George Heufelder

EVALUATON OF COARSE AGGREGATE
<u>BARNSTABLE COUNTY HEALTH</u>

REFERENCE NUMBER	M-12918
DATE RECEIVED	December 2, 2005
SPECIMEN	One sample of coarse aggregate. Sample was described as: "Double washed Stone, bucket #3, Cape Cod Aggregates".
METHOD OF ANALYSIS	Amount of Materials Finer than the #200 sieve by Washing ASTM C 117.
RESULTS	<u>Passing the #200</u> 0.2%
REMARKS	All testing was conducted at our Rockland Facility.

Respectfully submitted,

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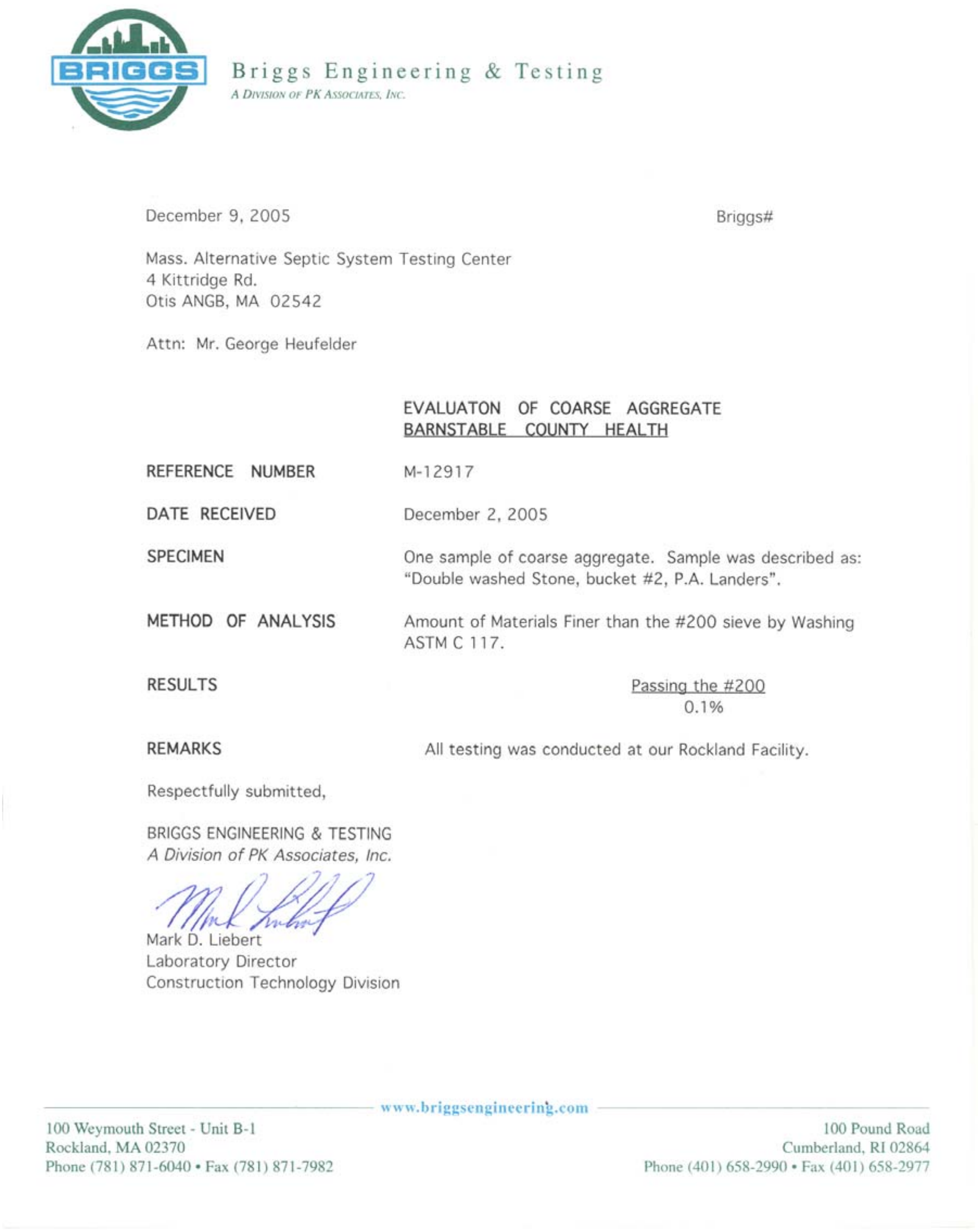

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December 9, 2005

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Attn: Mr. George Heufelder

EVALUATON OF COARSE AGGREGATE
BARNSTABLE COUNTY HEALTH

REFERENCE NUMBER	M-12917
DATE RECEIVED	December 2, 2005
SPECIMEN	One sample of coarse aggregate. Sample was described as: "Double washed Stone, bucket #2, P.A. Landers".
METHOD OF ANALYSIS	Amount of Materials Finer than the #200 sieve by Washing ASTM C 117.
RESULTS	Passing the #200 0.1%
REMARKS	All testing was conducted at our Rockland Facility.

Respectfully submitted,

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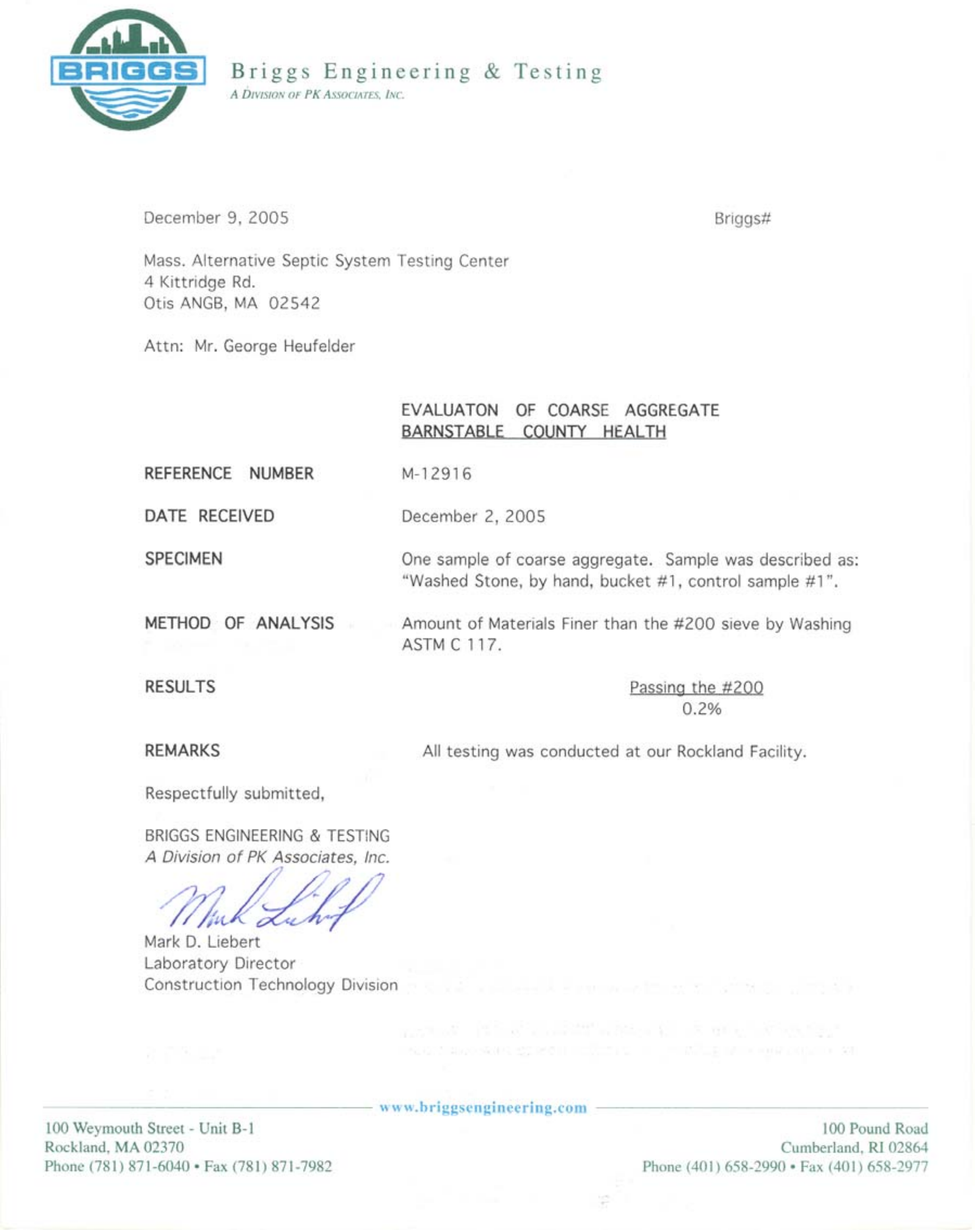

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EVALUATON OF COARSE AGGREGATE
BARNSTABLE COUNTY HEALTH

REFERENCE NUMBER M-12916

DATE RECEIVED December 2, 2005

SPECIMEN One sample of coarse aggregate. Sample was described as: "Washed Stone, by hand, bucket #1, control sample #1".

METHOD OF ANALYSIS Amount of Materials Finer than the #200 sieve by Washing ASTM C 117.

RESULTS

Passing the #200
0.2%

REMARKS All testing was conducted at our Rockland Facility.

Respectfully submitted,

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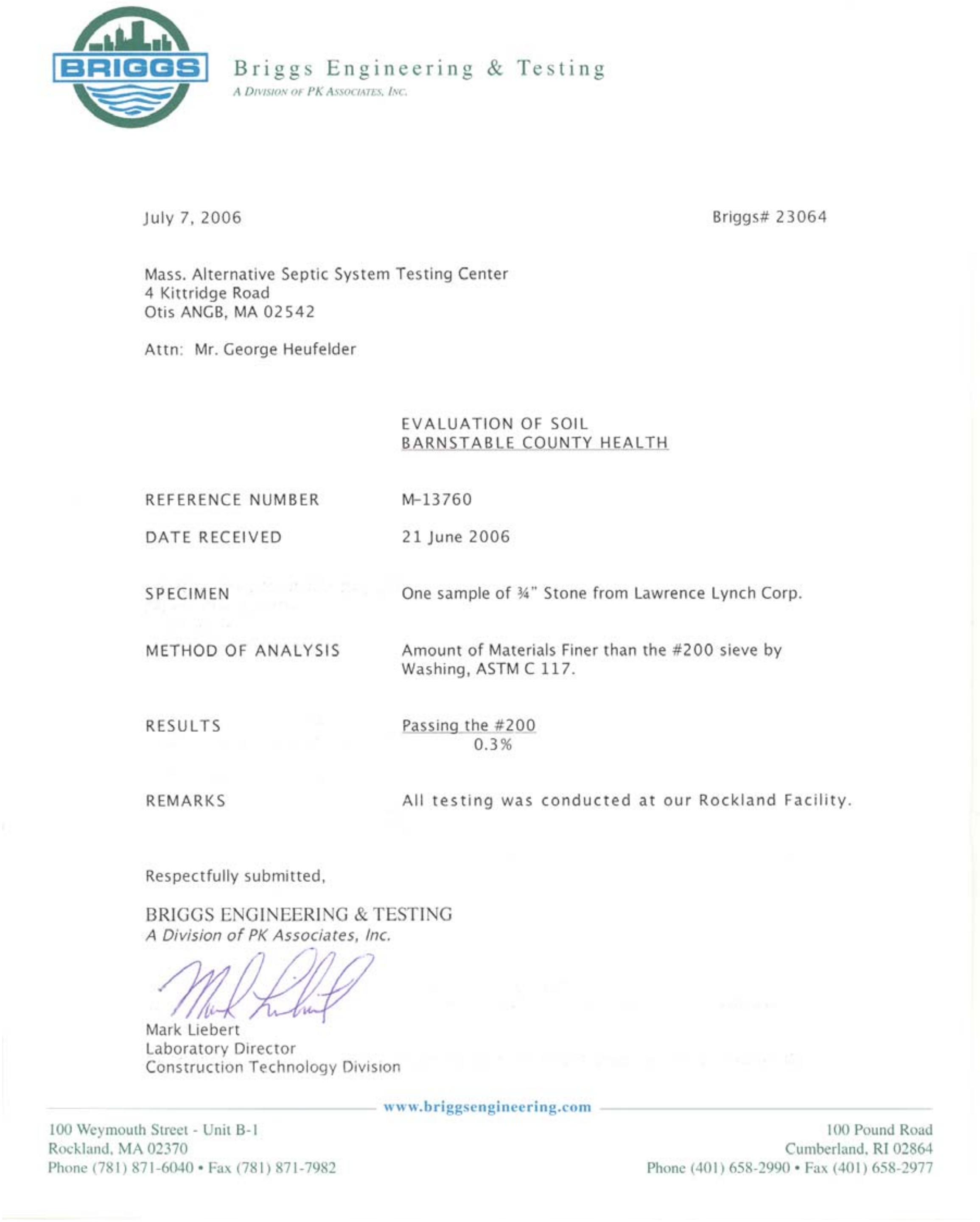

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Briggs Engineering & Testing
A Division of PK Associates, Inc.

July 7, 2006

Briggs# 23064

Mass. Alternative Septic System Testing Center
4 Kittridge Road
Otis ANGB, MA 02542

Attn: Mr. George Heufelder

EVALUATION OF SOIL
<u>BARNSTABLE COUNTY HEALTH</u>

REFERENCE NUMBER	M-13760
DATE RECEIVED	21 June 2006
SPECIMEN	One sample of ¾" Stone from Lawrence Lynch Corp.
METHOD OF ANALYSIS	Amount of Materials Finer than the #200 sieve by Washing, ASTM C 117.
RESULTS	<u>Passing the #200</u> 0.3%
REMARKS	All testing was conducted at our Rockland Facility.

Respectfully submitted,

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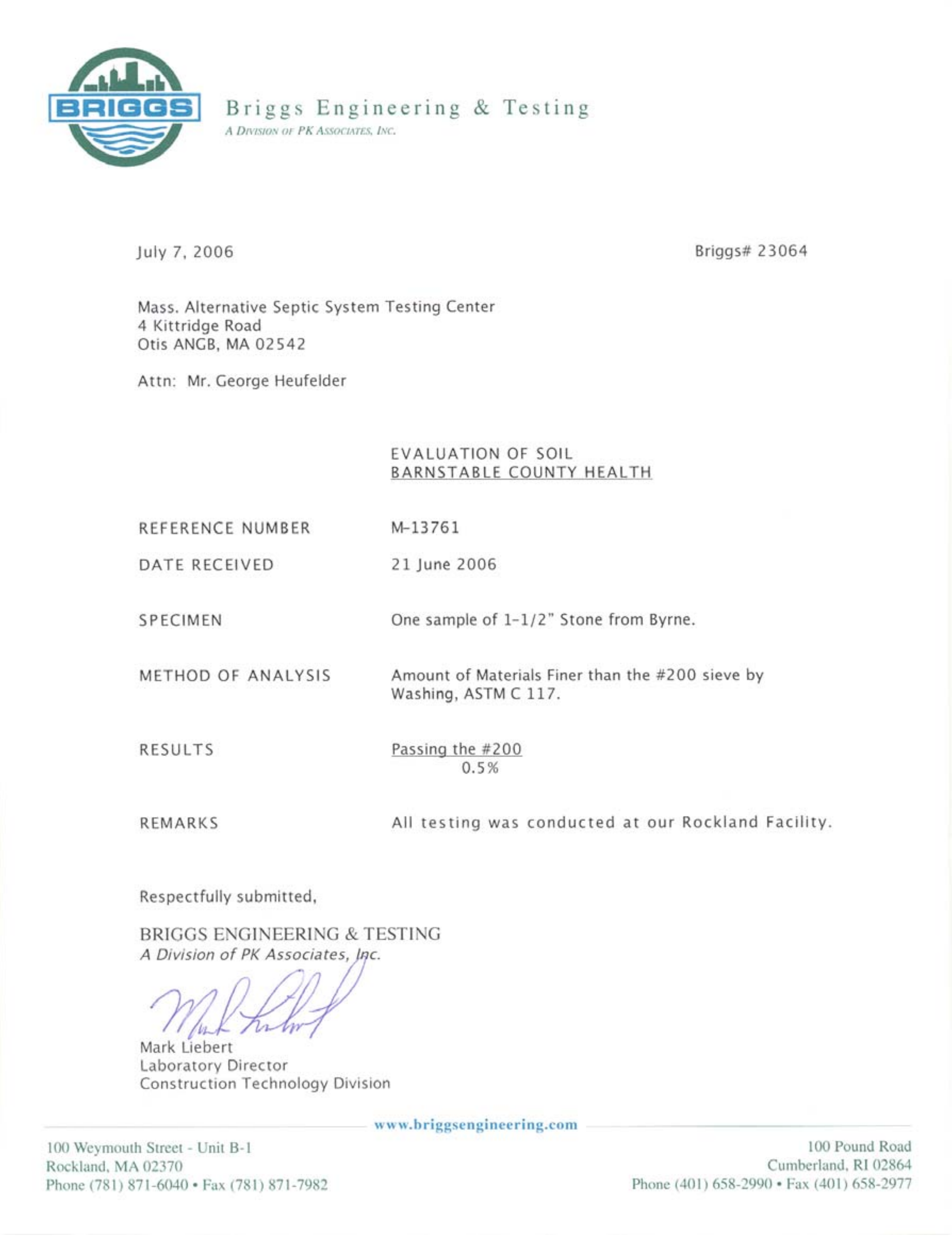

Briggs Engineering & Testing
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July 7, 2006

Briggs# 23064

Mass. Alternative Septic System Testing Center
4 Kittridge Road
Otis ANGB, MA 02542

Attn: Mr. George Heufelder

EVALUATION OF SOIL
BARNSTABLE COUNTY HEALTH

REFERENCE NUMBER	M-13761
DATE RECEIVED	21 June 2006
SPECIMEN	One sample of 1-1/2" Stone from Byrne.
METHOD OF ANALYSIS	Amount of Materials Finer than the #200 sieve by Washing, ASTM C 117.
RESULTS	Passing the #200 0.5%
REMARKS	All testing was conducted at our Rockland Facility.

Respectfully submitted,

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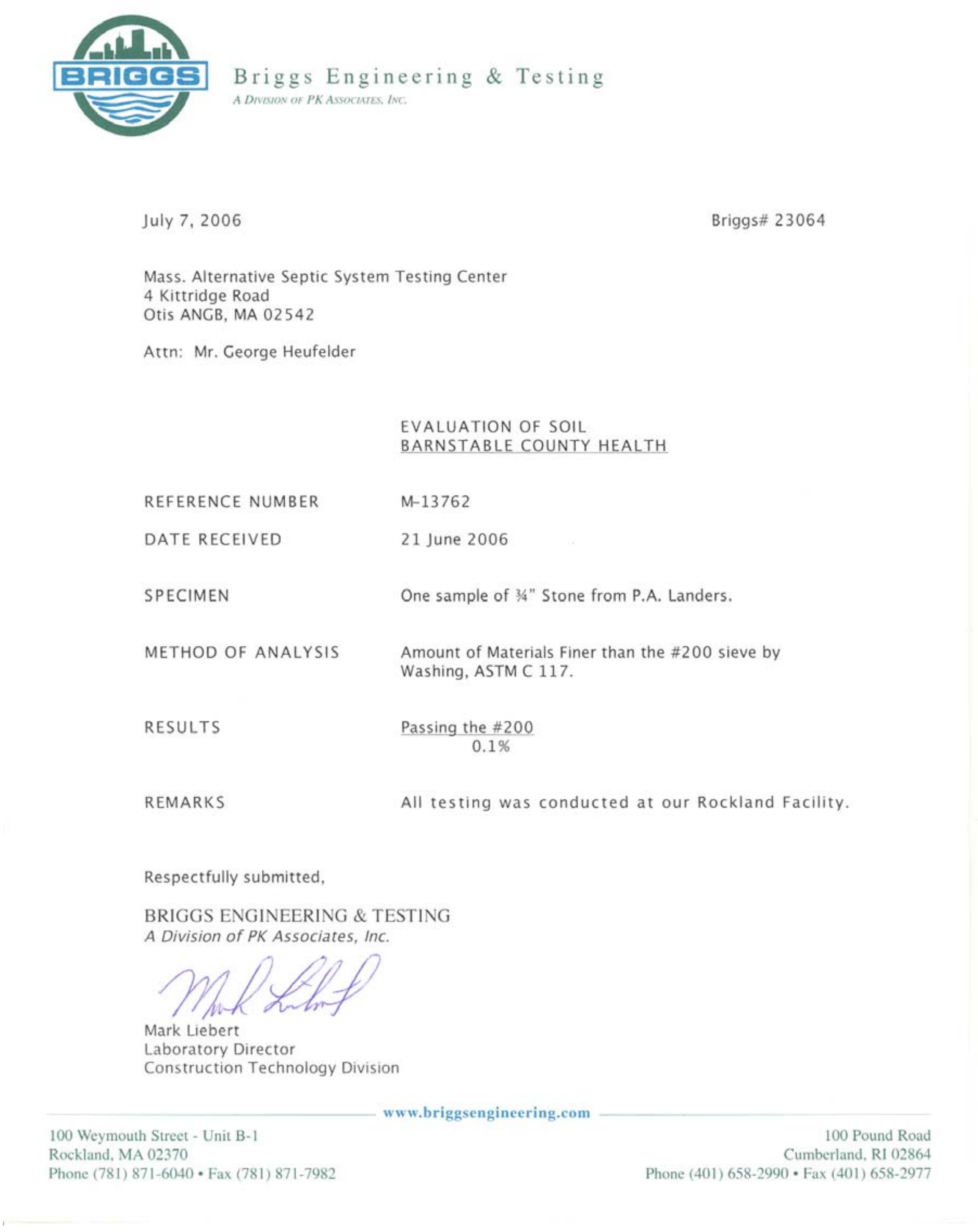

Briggs Engineering & Testing
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July 7, 2006

Briggs# 23064

Mass. Alternative Septic System Testing Center
4 Kittridge Road
Otis ANGB, MA 02542

Attn: Mr. George Heufelder

EVALUATION OF SOIL
BARNSTABLE COUNTY HEALTH

REFERENCE NUMBER	M-13762
DATE RECEIVED	21 June 2006
SPECIMEN	One sample of ¾" Stone from P.A. Landers.
METHOD OF ANALYSIS	Amount of Materials Finer than the #200 sieve by Washing, ASTM C 117.
RESULTS	Passing the #200 0.1%
REMARKS	All testing was conducted at our Rockland Facility.

Respectfully submitted,

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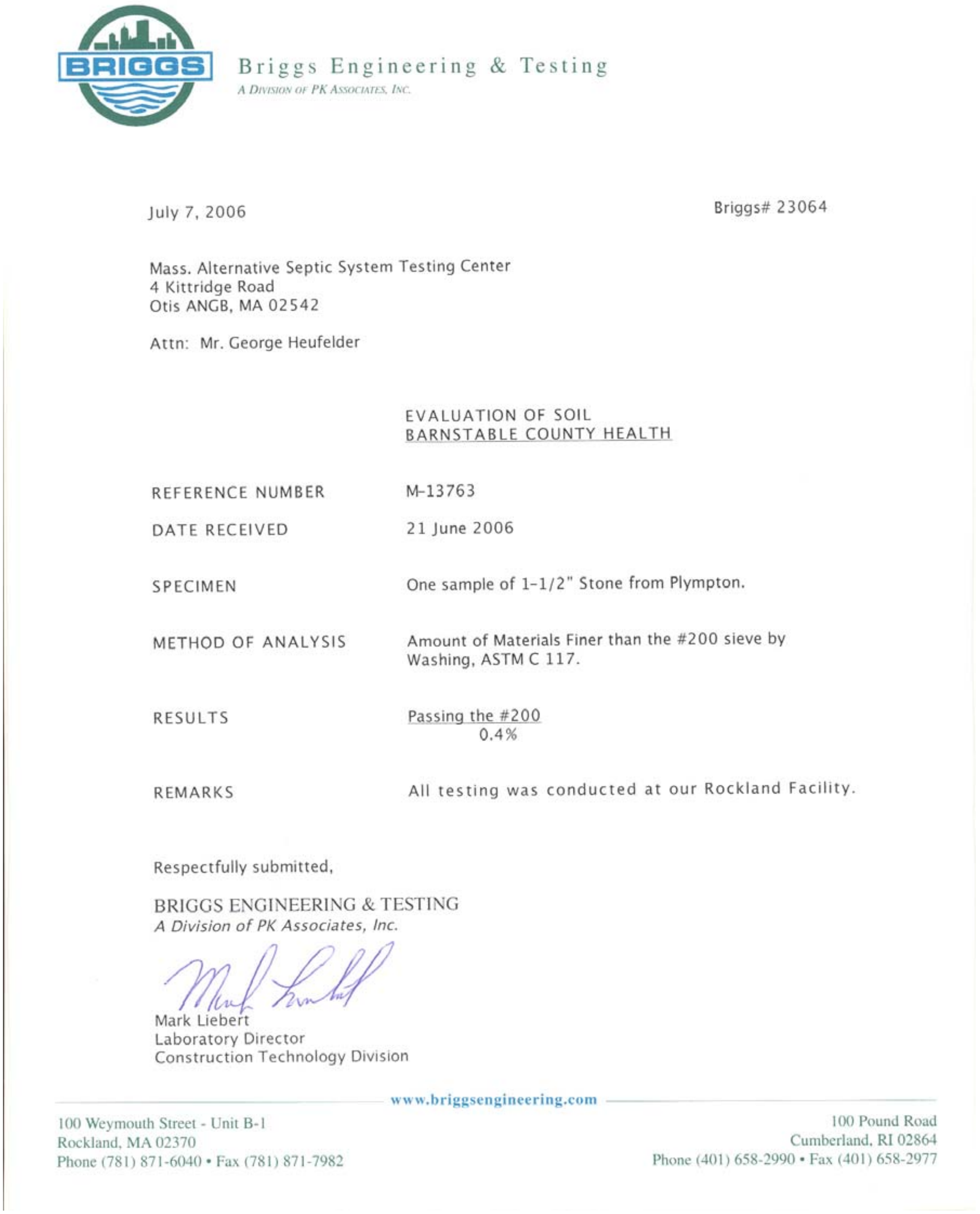

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July 7, 2006

Briggs# 23064

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Otis ANGB, MA 02542

Attn: Mr. George Heufelder

EVALUATION OF SOIL
BARNSTABLE COUNTY HEALTH

REFERENCE NUMBER	M-13763
DATE RECEIVED	21 June 2006
SPECIMEN	One sample of 1-1/2" Stone from Plympton.
METHOD OF ANALYSIS	Amount of Materials Finer than the #200 sieve by Washing, ASTM C 117.
RESULTS	Passing the #200 0.4%
REMARKS	All testing was conducted at our Rockland Facility.

Respectfully submitted,

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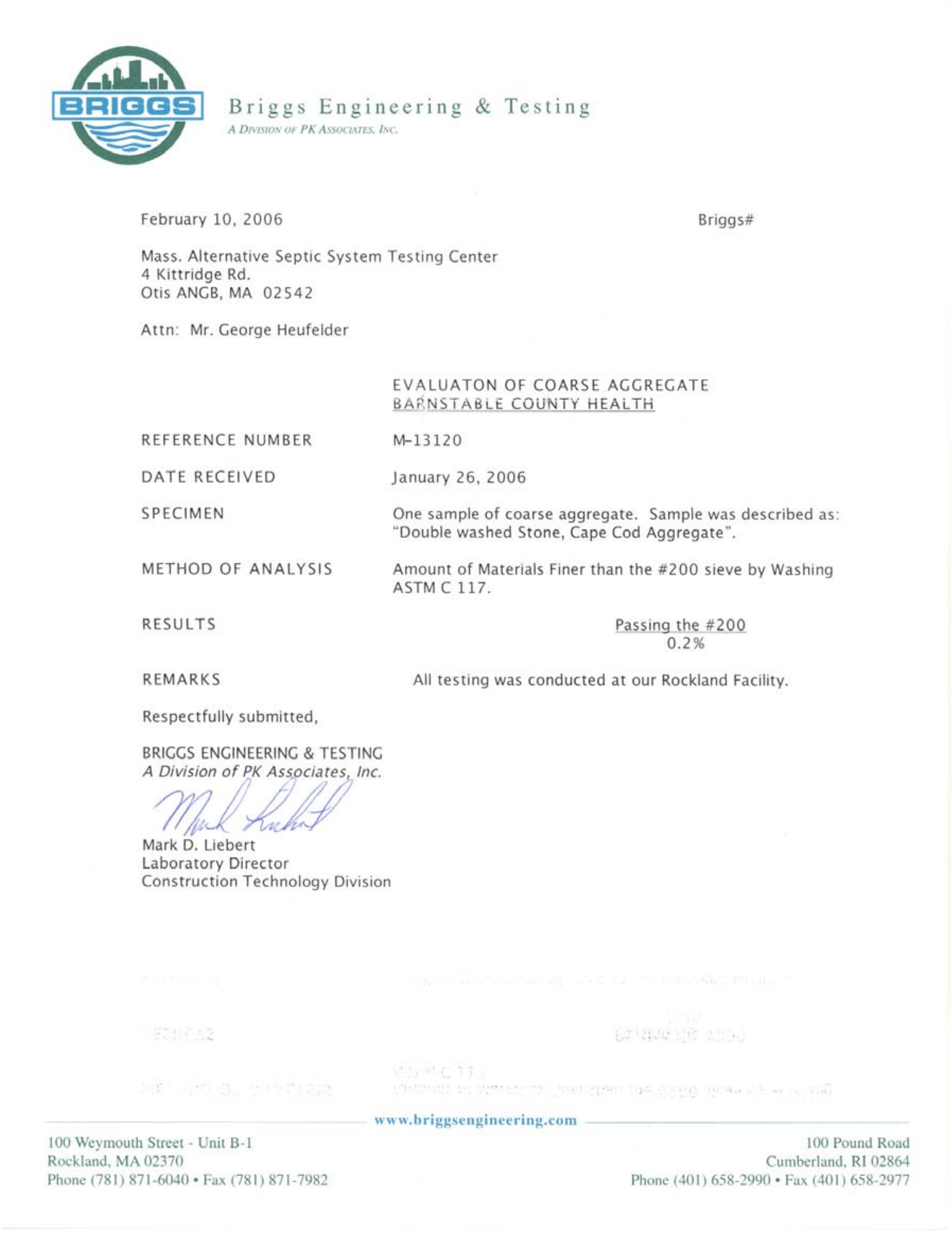

BRIGGS

Briggs Engineering & Testing
A Division of PK Associates, Inc.

February 10, 2006

Briggs#

Mass. Alternative Septic System Testing Center
4 Kittridge Rd.
Otis ANGB, MA 02542

Attn: Mr. George Heufelder

EVALUATON OF COARSE AGGREGATE
BARNSTABLE COUNTY HEALTH

REFERENCE NUMBER M-13120

DATE RECEIVED January 26, 2006

SPECIMEN One sample of coarse aggregate. Sample was described as: "Double washed Stone, Cape Cod Aggregate".

METHOD OF ANALYSIS Amount of Materials Finer than the #200 sieve by Washing ASTM C 117.

RESULTS

Passing the #200
0.2%

REMARKS All testing was conducted at our Rockland Facility.

Respectfully submitted,

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