TECHNICAL MEMORANDUM

TO:	Dr. Meg Garakani, Holcim	**DATE:**	May 29, 2007
FR:	Frank Shuri, Golder Associates Inc.	**OUR REF:**	073-93074.002
RE:	Reserve Silica Site: Soil Testing Results – Existing Cover at LDA		

1.0 BACKGROUND

During Golder's visit to the Reserve Silica site on April 20, 2007, bulk soil samples were collected from a hand-dug pit in the upper two feet of the existing soil cover on the Lower Disposal Area (LDA). Details of the location and sample collection process are presented in our Technical Memorandum *Visit to Reserve Silica Site, Ravensdale, Washington, April 20, 2007*, to Dr. Meg Garakani from Frank Shuri, dated April 27, 2007. As discussed in the site visit memo, water balance modeling indicates that a soil cover at the Reserve Silica site would need to have a hydraulic conductivity of 1 x 10^{-6} cm/sec or less to significantly reduce infiltration into the underlying materials. Based on visual observations of the soil collected during the site visit, it was not clear what value the in-place hydraulic conductivity was. Consequently, based on discussions between Holcim and Golder, it was decided to perform limited permeability testing on the soil samples collected during the site visit. This technical memo describes this testing program.

2.0 TESTING PROGRAM AND RESULTS

2.1 Existing Cover Soil

Two large plastic bag samples from the LDA cover, each weighing about 40 to 50 pounds, were shipped to Golder's geotechnical laboratory in Atlanta, Georgia, for testing. These samples were composited prior to testing to provide a uniform material with sufficient volume for the required tests; the composite sample would also simulate the effects of grading and mixing that are likely to occur during cover construction.

The particle size distribution of the composite sample was determined using ASTM D422. The results are shown on the attached lab sheet and indicate that the sample is well graded with a maximum particle size of about 3 inches. The composite soil consists of about 30% gravel, 41% sand, and 29% fines (i.e., soil passing the U.S. No. 200 sieve).

The moisture-density characteristics of the composite sample were then determined using ASTM D1557. These results were used for preparing a sample for permeability testing, and will also be useful to guide compaction efforts in the field. The moisture-density curve is shown on the attached lab sheet and indicates a maximum dry density of 115.4 pcf at a moisture content of 12.1%. For reference, the moisture content of the soil as received (i.e., reflecting field conditions) was 18.1%.

Using these results, a permeability test specimen was prepared by compacting the composite soil to 95% of the maximum dry density at a moisture content of about 3% above optimum. This density represents what could reasonably be achieved in the field using conventional equipment, and the moisture content is a typical value to reduce the permeability while still maintaining workability.

Permeability testing was performed in accordance with ASTM D5084. The sample was initially allowed to consolidate under a confining pressure of 2 psi, which simulates the vertical pressure at a depth of about two feet in the cover. The results indicated a hydraulic conductivity value of 5.1×10^{-7} cm/sec. The confining pressure was then increased to 5 psi, to simulate a typical pressure that would be applied by heavy compaction equipment, and the test was repeated. The hydraulic conductivity at a confining pressure of 5 psi decreased slightly to 1.1×10^{-7} cm/sec.

To confirm that the composite sample was not unduly reflecting the possible presence of finer-grained soil at the ground surface, a grain size test to determine the percentage of fines was performed on a jar sample collected from a depth of 18 inches, in accordance with ASTM D1140. This test indicated 26.4% fines, which, although slightly lower than the corresponding value for the composite sample, is for all practical purposes the same.

2.2 Admixed Cover Soil

As discussed in the site visit memo, there are three ponds on site which contain silt and clay from the sand washing process. Because it is fine-grained, this material could potentially reduce the hydraulic conductivity of the cover soil if admixed into the soil.

A sample from Pond 1 was sent to Golder's Denver, Colorado, geotechnical laboratory for testing. A sieve and hydrometer analysis was performed in accordance with ASTM D422. The results area shown on the attached lab sheet and indicate that this material consist of 98.8% fines, with about 22% clay (using the 0.002 mm criterion for clay size). Atterberg limits were also performed on this material in accordance with ASTM D4318 and indicated that the Pond 1 soil can be classified as a low-plasticity clay.

Approximately 10% by dry weight of Pond 1 material was then mixed with composite sample, and the testing program for moisture-density and permeability as described above was repeated for this admixed material. The moisture-density curve is shown on the attached lab sheet and indicates a maximum dry density of 117.1 pcf at a moisture content of 11.3%. The hydraulic conductivity results were 5.3×10^{-7} cm/sec and 8.8×10^{-8} cm/sec at 2 psi and 5 psi confining pressure, respectively.

3.0 DISCUSSION

These test results indicate that adding 10% of Pond 1 soil to the existing cover soil at the LDA did not change the permeability, within limits of normally expected variation.

A major uncertainty with this study is that the soil sample from the existing LDA cover represents only one location and depth, and therefore the degree of representativeness cannot be evaluated. However, the field description of this soil indicated that it was mine spoil. Geoprobe and soil boring investigations performed at the LDA by Arcadis during November 2002 suggest that mine spoil is laterally extensive over much of the LDA, often with thicknesses of 5 feet or greater.

On this basis, we do not believe that the additional cost associated with admixing Pond 1 material into the existing cover soils at the LDA is justified. However, we recommend that the cover soils be carefully observed during construction to verify that at least two feet of soil with a fines content of 25% or greater is present at all locations. This could be done at the end of regrading using a small rubber-tired backhoe to dig shallow holes at a number of locations. Soil samples would be collected and the fines content determined with ASTM D1140 (wash through the No. 200 sieve), a relatively quick and inexpensive test. If areas are identified where the soil does not have a sufficient fines content, Pond 1 material from a pre-placed contingency stockpile would be admixed as necessary.

Alternatively, a test pit and soil sampling program could be performed as part of final design to determine if there is any need for admixing, and, if so, determine the required volumes of Pond 1 material. The advantage of this approach is that the construction activities would be clearly established and the need for excavating, hauling, drying, and stockpiling Pond 1 soil would be minimized.

It should be noted that the laboratory permeability values measured in this testing program may not be representative of the actual permeability of the cover in the field. Because laboratory testing is performed on carefully prepared, homogeneous samples, the results can be up to an order of magnitude lower than would be measured in the field. The upper layers of the cover in place can be more permeable due to roots, cover desiccation (clay shrinkage) during the summer months, and other factors. Thus, while the results of this study are encouraging with respect to the ability of the cover at the LDA to reduce infiltration, they should not be considered definitive. In any case, however, admixing the existing cover soil with Pond 1 soil would not mitigate the factors that increase permeability in the field.

Lab Results Tech Memo 2007-05-29.doc

HOLCIM/ENERGIS/RESERVE SILICA/WA
SUMMARY OF SOIL DATA

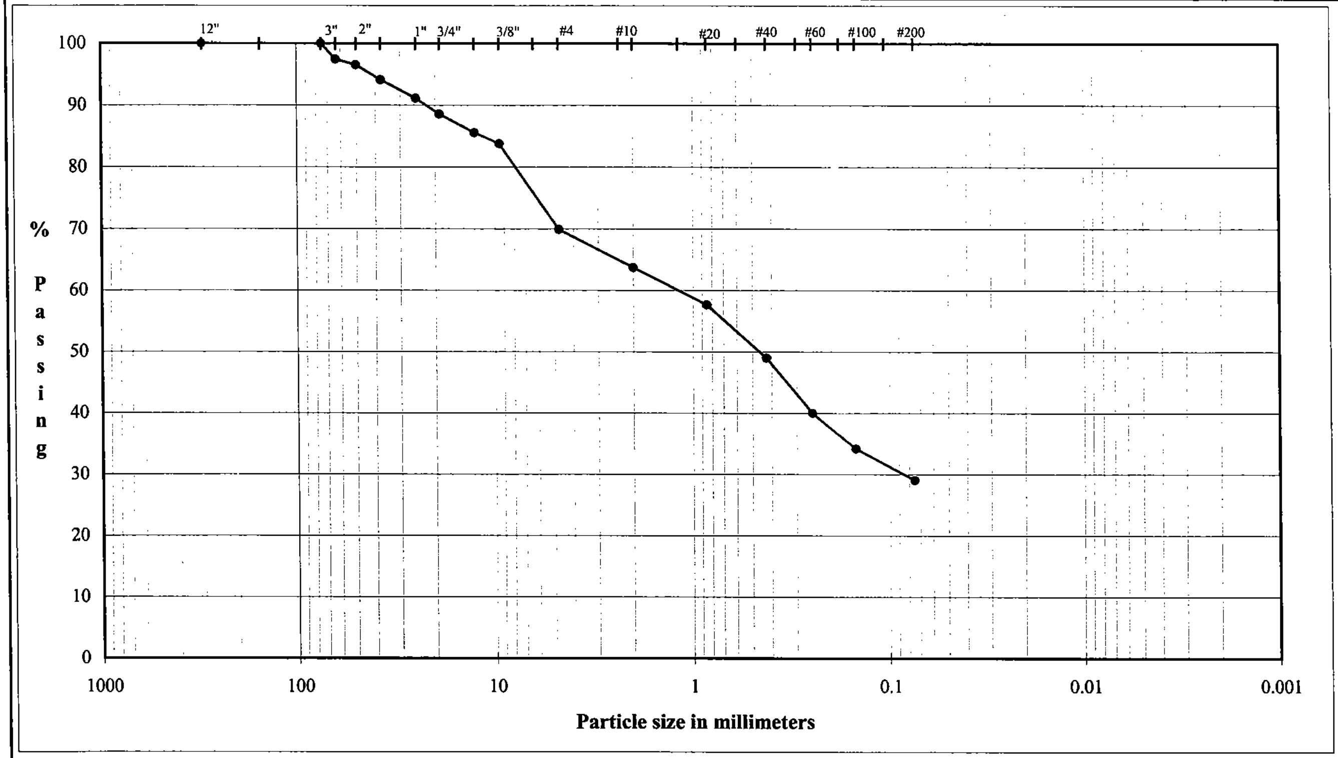
Test Pit Identification	Sample Type	Sample Depth	Soil Classi-fication	Natural Moisture %	Atterberg Limits				Grain Size Distribution			Compaction			Unit Weight		Permeability (cm/sec)	Confining Pressure (psi)
					L.L.	P.L.	P.I.	L.I.	% Finer No. 4 Sieve	% Finer No. 200 Sieve	% Finer .005 mm	Maximum Dry Density (lb/cuft)	Optimum Moisture %	Gs	Moisture %	Dry (lb/cuft)		
LDA-1	Bulk	0 - 24" Composite	SC	18.1	-	-	-	-	69.9	29.1	-	115.4	12.1		17.2	104.5	5.1E-07	2
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1E-07	5
LDA-1	Jar	18"	-	-	-	-	-	-	-	26.4	-	-	-	-	-	-	-	-
Pond 1	Bulk	0-8"	CL	77.3	49	28	21	-	100.0	98.8	47.0	-	-	2.65	-	-	-	-
LDA-1 & Pond 1 Mix	Bulk	0-24"	SC	15.6	-	-	-	-	-	-	-	117.1	11.3	-	16.3	105.9	5.3E-07	2
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.8E-08	5

ABBREVIATIONS: LIQUID LIMIT (LL)
PLASTIC LIMIT (PL)
PLASTICITY INDEX (PI)
LIQUIDITY INDEX (LI)
SPECIFIC GRAVITY (Gs)
MOISTURE (Mc)

PARTICLE SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

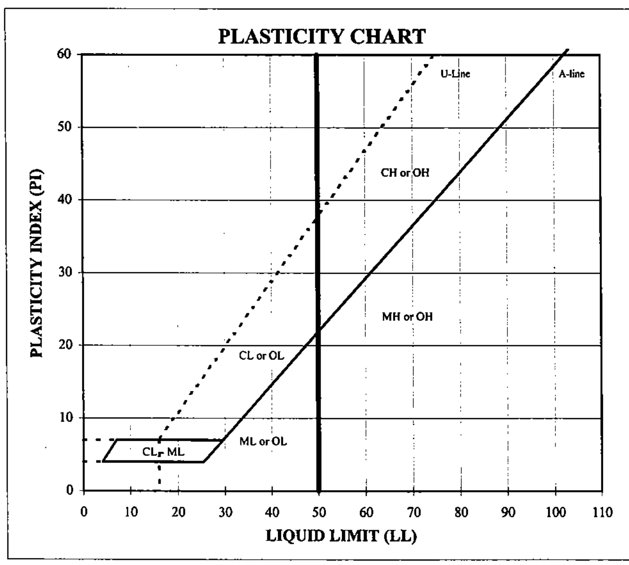
PROJECT NAME: **HOLCIM/ENERGIS/RESERVE SILICA/WA**
SAMPLE ID: **LDA 1 & 2** Depth: **0 - 24"**
TYPE: **Bulk**



	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay
COBBLES	GRAVEL		SAND			FINES

U.S. Standard Sieves Sizes and Numbers

U.S. Standard Sieves Sizes and Numbers	Particle Size (mm)	% Passing	Particle Size Classification	Percentage
12.0"	304.8	**100.0**		
3.0"	75.0	**100.0**	Cobbles	**0.00**
2.5"	63.5	**97.4**		
2.0"	50.0	**96.5**		
1.5"	37.5	**94.1**		
1.0"	25.0	**91.1**		
0.75"	19.0	**88.6**	Coarse Gravel	**11.43**
0.50"	12.7	**85.6**		
0.375"	9.5	**83.8**		
#4	4.8	**69.9**	Fine Gravel	**18.69**
#10	2.00	**63.7**	Coarse Sand	**6.16**
#20	0.85	**57.7**		
#40	0.43	**49.0**	Medium Sand	**14.70**
#60	0.25	**40.0**		
#100	0.15	**34.2**		
#200	0.075	**29.1**	Fine Sand	**19.95**
			Fines	**29.07**



ATTERBERG LIMITS

Method -B (Dry preparation)

M_c	LL	PL	PI	LI
18.1				

DESCRIPTION: Dark Gray, COARSE TO FINE SAND AND COARSE TO FINE GRAVEL, some silty clay.

USCS: (SC)

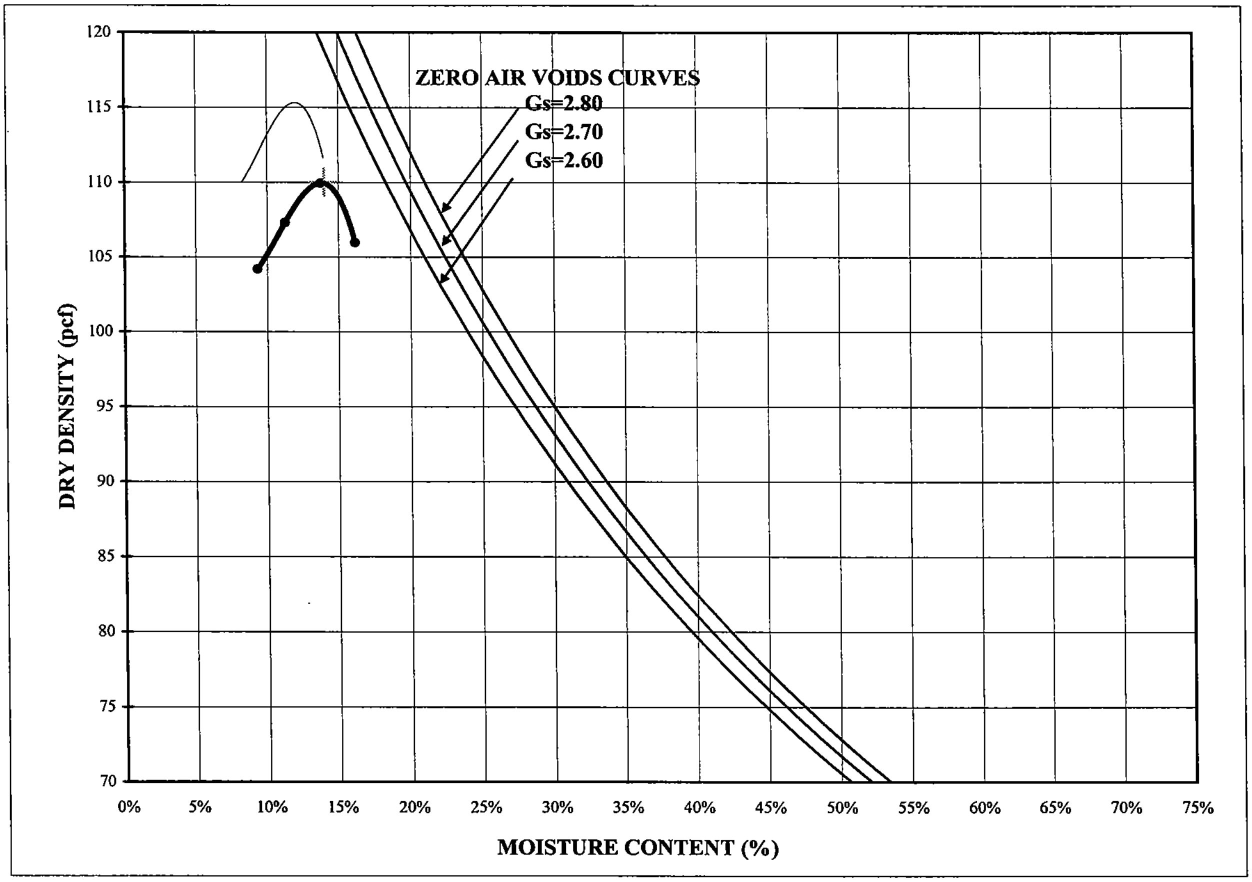
LL (oven-dried)	
< 0.75 = ORGANIC (OL/OH)	

TECH	AK/BW
DATE	05/12/07
CHECK	
REVIEW	

MOISTURE / DRY DENSITY CURVE
ASTM D 1557 Method B

Mechanical	Modified	Wet Method

PROJECT NAME: HOLCIM/ENERGIS/RESERVE SILICA/WA
PROJECT NUMBER: 073-93074
SAMPLE ID: LDA 1 & 2 **Composite** DEPTH: 0 - 24" SAMPLE TYPE: **Bulk**



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	104.2	9.3%
2	107.3	11.3%
3	109.9	13.8%
4	106.0	16.2%

Maximum Dry Density (pcf)	110.0
Optimum Moisture (%)	14.0
Corrected Maximum Dry Density (pcf)	115.4
Corrected Optimum Moisture (%)	12.1
As-Received Moisture Content	18.1%
% Retained on # 4 sieve	30.1%
% Retained on 3/8" sieve	16.2%
% Retained on 3/4" sieve	

DESCRIPTION Dark Gray, COARSE TO FINE SAND AND COARSE TO FINE GRAVEL, some silty clay.

USCS (SC)

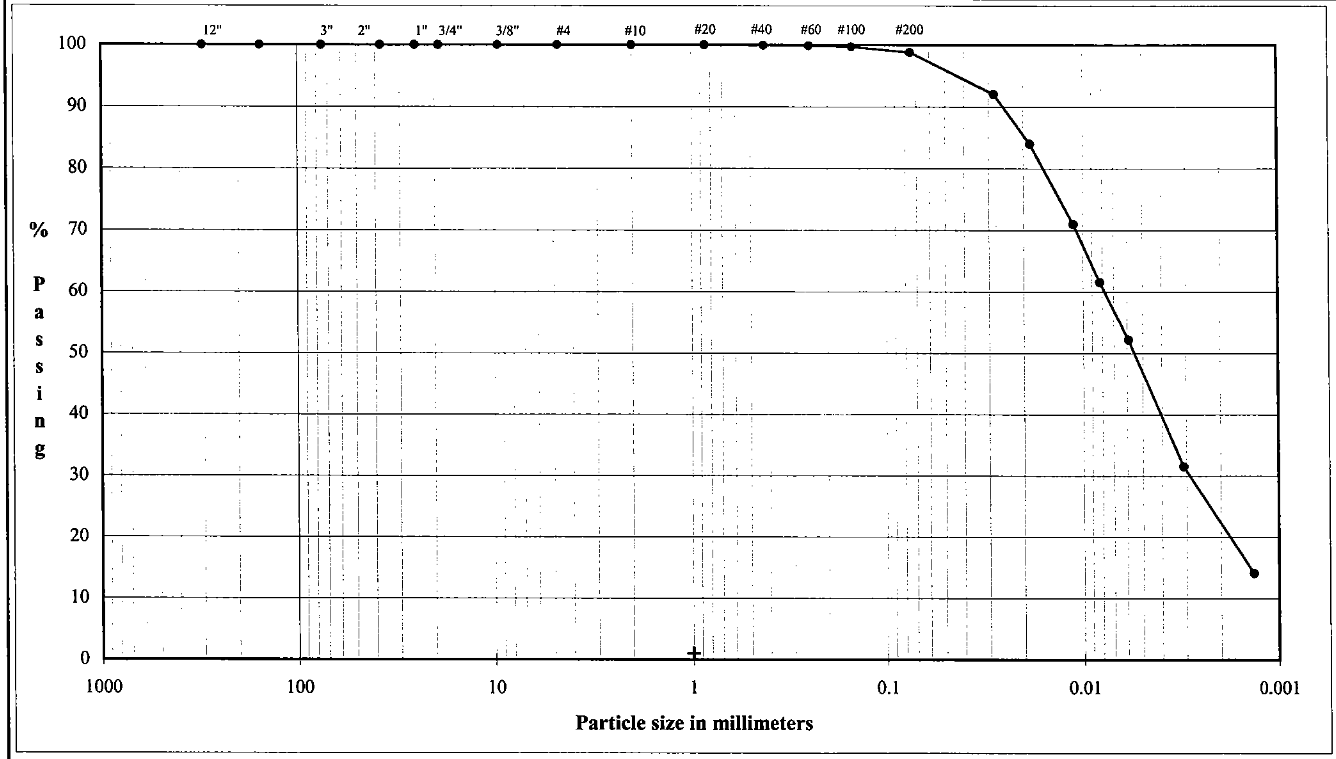
CHECK

REVIEW

PARTICLE-SIZE DISTRIBUTION & ATTERBERG LIMITS

ASTM D421, D422, D4318

PROJECT NAME: **Holcum/Energis/Reserve Silica/WA**
SAMPLE ID: **Pond 1** Depth (ft): --
TYPE: **Bag**



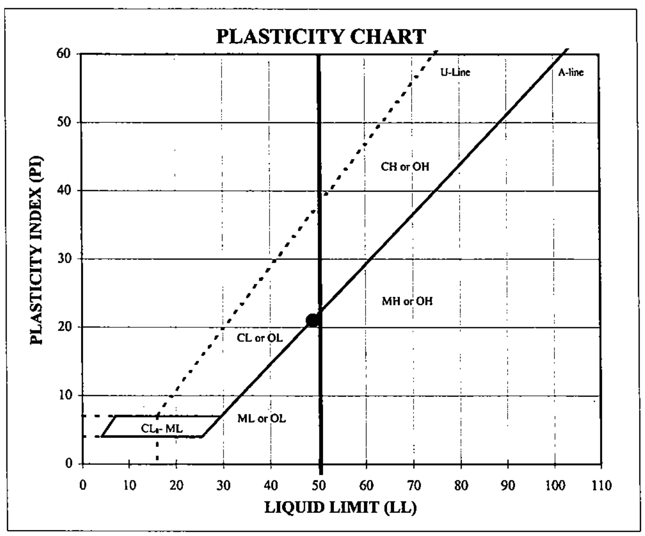
COBBLES	GRAVEL		SAND			FINES
	Coarse	Fine	Coarse	Medium	Fine	Silt or Clay

U.S. Standard Sieves Sizes and Numbers

	Particle Size (mm)	% Passing	Particle Size Classification	Percentage
12.0"	304.8	**100.0**		
12.0"	304.8	**100.0**	Cobbles	**0.00**
6.0"	154.2	**100.0**		
6.0"	154.2	**100.0**		
3.0"	75.0	**100.0**		
1.5"	37.5	**100.0**		
1.0"	25.0	**100.0**	Coarse Gravel	**0.00**
0.75"	19.0	**100.0**		
0.375"	9.5	**100.0**		
#4	4.8	**100.0**	Fine Gravel	**0.00**
#10	2.00	**100.0**	Coarse Sand	**0.00**
#20	0.85	**100.0**		
#40	0.43	**99.9**	Medium Sand	**0.06**
#60	0.25	**99.9**		
#100	0.15	**99.7**		
#200	0.075	**98.8**	Fine Sand	**1.14**

Hydrometer Analysis

(mm)	%Finer		
0.028	**92.0**		
0.018	**84.0**		
0.011	**71.0**		
0.008	**61.6**	Fines Silt or Clay	**98.80**
0.006	**52.2**		
0.003	**31.5**		
0.001	**14.1**		



ATTERBERG LIMITS

M_c	LL	PL	PI	SpG
77.3	49	28	21	2.65

DESCRIPTION: Yellow silt

USCS: ML

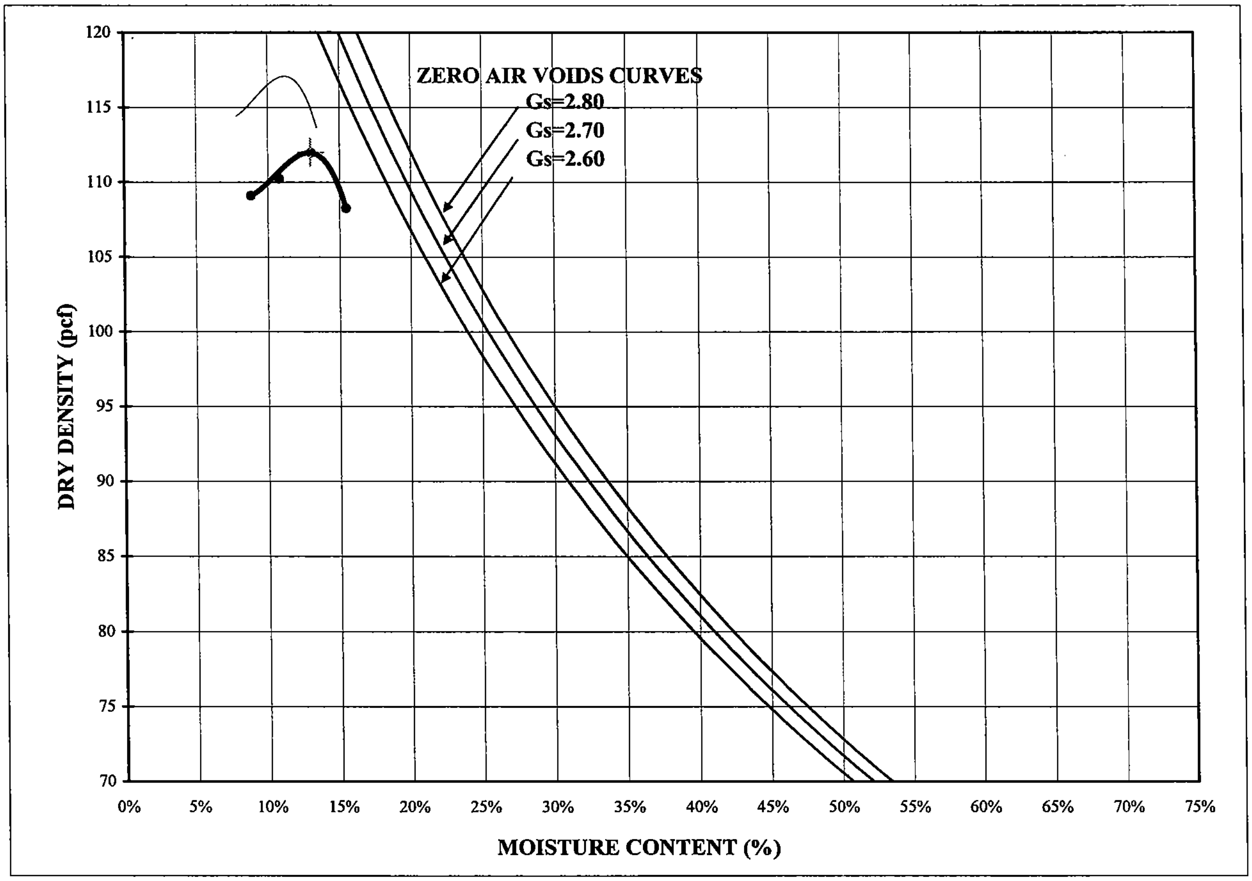
TECH	CS
DATE	5/4/2007
REVIEW	MB

Golder Associates Inc.

MOISTURE / DRY DENSITY CURVE
ASTM D 1557 Method B

Mechanical	Modified	Wet Method

PROJECT NAME: **HOLCIM/ENERGIS/RESERVE SILICA/WA**
PROJECT NUMBER: **073-93074**
SAMPLE ID: **LDA 1 & 2 Mix** DEPTH: **0 - 24"** SAMPLE TYPE: **Bulk**



COMPACTION POINTS		
Specimen Number	Dry Density (pcf)	Moisture Content (%)
1	109.1	8.8%
2	110.2	10.8%
3	112.0	13.1%
4	108.3	15.5%

Maximum Dry Density (pcf)	112.0
Optimum Moisture (%)	13.0
Corrected Maximum Dry Density (pcf)	117.1
Corrected Optimum Moisture (%)	11.3
As-Received Moisture Content	15.6%
% Retained on # 4 sieve	30.1%
% Retained on 3/8" sieve	15.8%
% Retained on 3/4" sieve	

DESCRIPTION Dark Gray, COARSE TO FINE SAND AND COARSE TO FINE GRAVEL, some silty clay.

USCS (SC)

CHECK

REVIEW