M. Soil Consultants

Date: February 22, 2006

RE: Gradation Analysis and Permeability Tests
(Dam construction proposal- Peter Piper)

I have completed the required tests for Piper Associates on the foundation soil of the dam construction site, as well as the soil proposed as a filter material. Attached is the report for your review prior to mailing.

If you have any questions, please contact me by e-mail, xxx@umich.edu, or phone, xxx.

Attachments

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M. Soil Consultants

February 22, 2006

Peter Piper
Assistant Manager
William Piper Associates
6272 Stadium Boulevard
Ann Arbor, MI 48108

RE: **Gradation Analysis and Permeability Tests (Glacier Way Dam)**

Dear Mr. Piper:

SUMMARY
You recently requested that our department conduct a series of tests on a soil found at the proposed site of a new 100' long masonry dam, as well as tests on a coarse soil to be used as a filter material. You are concerned with the classification of the soils, their suitability for this construction, and the resulting seepage loss under the dam. Our results show the coarse sand is suitable for filter material, classified by ASTM as SP- Poorly Graded Sand. The foundation soil is classified by ASTM as SC- Clayey Sand. The use of the Hazen equation to find permeability was found to be significantly inaccurate. However, using our test data for permeability, Design #1 will have seepage of 0.274 ft^3/day while Design #2 will have seepage of 0.164 ft^3/day. We recommend lowering these seepage values in both designs by incorporating a 75' clay blanket on the water bed of the head end of the dam.

INTRODUCTION
Your letter, sent on January 25, 2006, asked for us to test two soils to be used in the construction of a new masonry dam at your Glacier Way site. You are concerned with ASTM soil classification, suitability of the coarse soil as a filter material, and the effective seepage underneath the two different dam designs, both 100' in length. It's apparent that a series of tests must be conducted to find the gradation curves and permeability of each soil. The appropriate testing has been completed, and we submit our findings in this report.

SOIL DESCRIPTION
Tests were performed on two different soil samples. Both were a dry and brown sand common to this area of Michigan. The first was very fine and was found locally in the excavation site of the new dam. The second was an external sand brought in to be used as a filter, being similar to the first, however more coarse in nature. Further tests were performed on each sample to find their ASTM classifications, gradation analysis, and respective permeability.

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TEST PROCEDURE

The following tests were performed on the soil samples:

ASTM D-422: Sieve Analysis (coarse and fine)
ASTM D-422: Hydrometer Analysis (fine only)
ASTM D-2434: Constant Head Permeability Test
ASTM D-5856: Falling Head Permeability Test

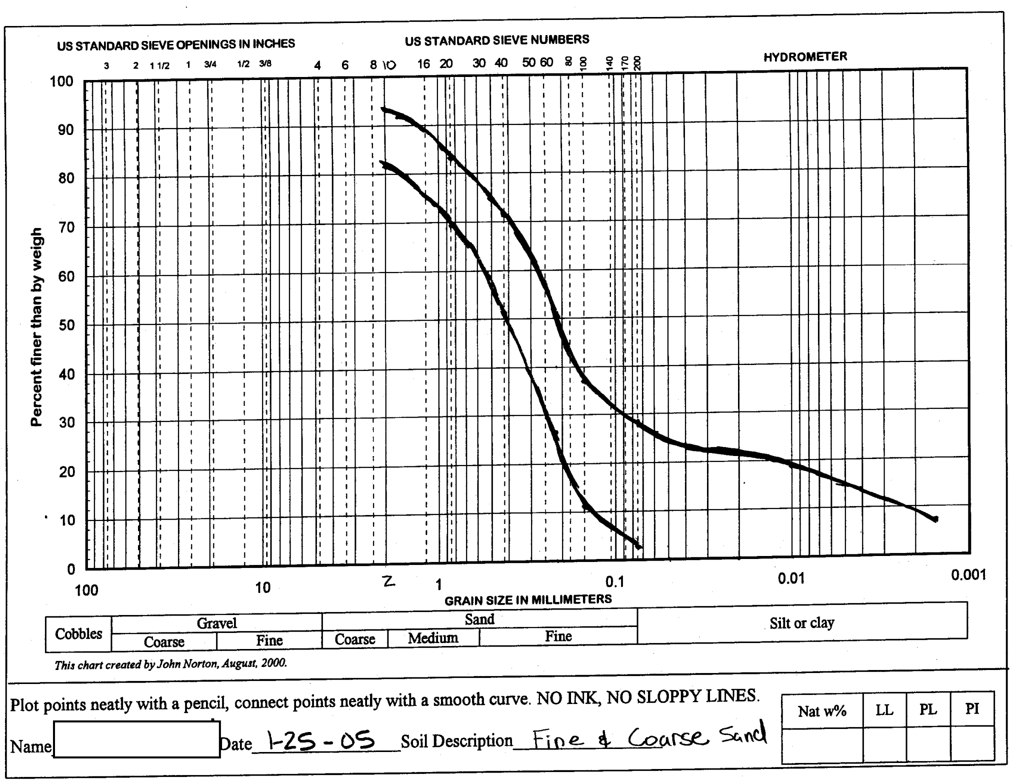
Test -422 uses the shaking sieve method well known among engineers to analyze the gradation of soils. The -422 hydrometer test uses a standard hydrometer setup and data points are taken over a 18 hour period to determine the size gradation of finer soils.
Test -2434 uses an apparatus that keeps a constant head of water while allowing water to flow through a sample of soil. Time and the volume of water flowing are used to get flow rate, and thus the coefficient of permeability for the soil.
Test -5856 is similar to -2434 and the same data is recorded, however it allows the head of the water to fall over time. Likewise, the method of calculating the coefficient of permeability varies slightly.

All procedures were *followed generally*, and can be referenced in the CEE 445 laboratory course pack.

TEST RESULTS

Shown below in Figure 2.1 is the graph of the grain size distribution curve of each soil, with the coarse sand on the left and the fine on the right. Full data sheets of the sieve analysis can be seen in Appendix A and the data for the hydrometer test can be seen in Appendix B.

FIGURE 2.1: Grain Size Distribution Curves



Using the sieve analysis results, Table 3.1 below shows each soil classified according to standards set by ASTM. Calculations to determine classifications can be found in Appendix D.

TABLE 3.1: ASTM Soil Classification

Soil	Classification
Fine	**SC - *Clayey Sand***
Coarse	**SP - *Poorly Graded Sand***

The US Army Corps of Engineers sets criteria on soils used as filter material:

$$\mathbf{D_{15\ filter} \leq 5 \cdot D_{85\ soil}} \qquad \mathbf{D_{50\ filter} \leq 25 \cdot D_{50\ soil}} \qquad \mathbf{D_{15\ filter} \geq 5 \cdot D_{15\ soil}}$$

0.17 ≤ 5(0.91) <u>(OK)</u> **0.41 ≤ 25(0.21) <u>(OK)</u>** **0.17 ≥ 5(0.005) <u>(OK)</u>**

The permeability of the fine soil can be estimated using the Hazen's Equation:

$$\mathbf{k\ (cm/s) = D_{10}^{\ 2}} \quad \textit{(with } D_{10} \textit{ in mm)}$$

$$k = (0.00225)^2 \approx \mathbf{5.06\ (10^{-6})\ cm/s}$$

Shown below in Table 3.2 are the calculated values for the soils' permeability. Full data sheets can be referenced in Appendix C.

TABLE 3.2: Soil Permeability

Soil	Permeability
Fine	**1.74 (10^{-6}) cm/s**
Coarse	**9.20 (10^{-3}) cm/s**

The calculated value of the permeability using the Hazen's Equation is shown to be pretty inaccurate compared to that of the test results. The Hazen's Equation gives a value almost 3 times larger than the actual tested value. The main reason for this being that Hazen designed the equation to be generally accurate with uniform soils in a relatively loose condition, and our soil is graded well and is far from a uniform state. Moreover, it is merely an empirical formula and can not be accurate in all cases.

Given your attached masonry dam designs with drawn flownets, we were able to compute the seepage underneath each dam design. Calculations can be found in Appendix D.

Design #1 - Q = 0.274 ft^3/day

Design #2 - Q = 0.164 ft^3/day

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CONCLUSIONS
Our results indicate that both dam designs will have to large of a resulting seepage. We recommend that a 75’ clay blanket be introduced on the water bed at the head of the dam. This in turn will increase the travel distance of the flow channels for water, thus lowering effective seepage of the dam.

Design #1 was found to have a higher seepage of 0.274 ft^3/day than Design #2, which had a seepage of 0.164 ft^3/day. The foundation soil of the dam is classified as SC - Clayey Sand. The soil proposed in Design #1 as a berm is classified as SP - Poorly Graded Sand, and meets all Army Corps of Engineers criteria of soils to be used as filter material. In conclusion, both dams are adequate for construction with the addition of a clay blanket, and all soils meet criteria set forth by the Army Corps of Engineers and ASTM.

If you any questions please feel free to contact us at xxx.

Very truly yours,

Engineering Manager

Attachments
GGB:bp

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APPENDICES

APPENDIX A: SIEVE ANALYSIS DATA

APPENDIX B: HYDROMETER TEST DATA

APPENDIX C: PERMEABILITY DATA

APPENDIX D: CLASSIFICATION & SEEPAGE CALCULATIONS

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APPENDIX A: SIEVE ANALYSIS DATA

Lab Number 3 – Sieve Analysis (ASTM D-422)

Name

Date 1-25-05

Material Fine Sand Source Bucket

Weight of dray sample and container, g	568.8
Weight of container, g	80.5
Weight of dry sample, g	488.3

Sieve No.	Size, mm	Weight Sieve, g	Weight, sieve and soil, g	Weight retained, g	Percent retained	Cumulative percent retained	Percent Passing
10	2	451.8	484.4	32.6	6.7	6.7	93.3
20	.85	4246	474.5	49.9	10.2	16.9	83.1
40	.42	389.2	446.4	57.2	11.7	28.6	71.4
70	.21	430.9	526.6	95.7	19.6	48.2	51.8
100	.15	339.0	410.4	71.4	14.6	62.8	37.2
200	.075	345.3	388.5	43.2	8.9	71.7	28.3
Pan	—	424.1	561.9	137.8	28.3	100	0
				$\boxed{487.8}$			

Lab Number 3 – Sieve Analysis (ASTM D-422)

Name

Date 1-25-05

Material Coarse Sand Source Bucket

Weight of dray sample and container, g	575.0
Weight of container, g	80.5g
Weight of dry sample, g	494.5g

Sieve No.	Size, mm	Weight Sieve, g	Weight, sieve and soil, g	Weight retained, g	Percent retained	Cumulative percent retained	Percent Passing
10	2	451.2	540.0	88.8	18	18	82
20	.85	424.5	487.4	62.9	12.7	30.7	69.3
40	.42	387.7	478.7	91	18.4	49.1	50.9
70	.21	430.3	550.1	119.8	24.3	73.4	26.6
100	.15	339.0	416.2	77.2	15.6	89	11
200	.075	345.3	387.7	42.4	8.6	97.6	2.4
Pan	—	424.1	436.0	11.9	2.4	100	0
				$\boxed{494g}$			

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APPENDIX B: HYDROMETER TEST DATA

Hydrometer Test

Performed By:		Date of Test:	2-1-05
Hydrometer Type:	152 H	Mass of Dry Soil + Dish:	99.84 g
Dispersing Agent:	Sodium Hexameta Phosphate	Mass of Dish:	49.83 g
Meniscus Height, H_m:	1 divisions	Mass of Dry Soil ($W_{s\ tot}$):	50.01 g
Zero Correction, R_z:	6 divisions	Specific Gravity (G_s):	2.76
% Passing #200:	28.3 %	Spec. Grav. Corr. (a):	0.976

Elapsed Time, t (min)	Actual Reading, R_a (divisions)	Temp. T (°C)	Temp. Correction, C_T (divisions) *Table 6-3*	K *Table 6-4*	Corrected Reading, R_c (divisions)	Percent Finer than D (%)	Reading Corrected for Meniscus, R_m (divisions)	Length, L (use R_m) (cm) *Table 6-5*	Diameter, D (mm)	Normalized Percent Finer (%)
0.25	(55) 54	20°C	N/A	0.0133	48	93.7	55	7.3	0.072	26.5
0.5	(53) 52				46	89.8	53	7.6	0.052	25.4
1	(51) 50				44	85.9	51	7.9	0.037	24.3
2	(49.5) 48				42	82.0	49	8.3	0.027	23.2
4	45				39	76.1	46	8.8	0.020	21.5
8	42				36	70.3	43	9.2	0.014	19.9
16	40				34	66.4	41	9.6	0.010	18.8
30	36				30	58.5	37	10.2	0.0078	16.6
60	33				27	52.7	34	10.7	0.0056	14.9
120	29				23	44.9	30	11.4	0.0041	12.7
18hr	20				14	27.3	21	12.9	0.0015	7.7

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APPENDIX C: PERMEABILITY DATA

Constant Head Permeability Test
Determination of Coefficient of Permeability

Test No.	1	2	3
Average flow, Q (cm^3)	162.3	194	186
Time of collection, t (s)	26.13	25	30
Temperature of water, T (°C)	20°	20°	20°
Head difference, h (cm)	147.5	147.5	147.5
Diameter of specimen, D (cm)	6.40	6.40	6.40
Length of specimen, L (cm)	6.50	6.50	6.50
Area of specimen, $A = \frac{\pi}{4}D^2$ (cm^2)	32.17	32.17	32.17
$k = \frac{QL}{Aht}$ (cm / s)	8.51(10^{-3})	1.06(10^{-2})	8.49(10^{-3})
Average k = 9.2(10^{-3}) cm/s			
$k_{20°C} = k_{T°C}\frac{\eta_{T°C}}{\eta_{20°C}}$ = N/A = ______ cm/s			

Constant Head Permeability Test
Determination of Void Ratio of Specimen

Description of soil Coarse Sand Sample No. 001

Location G. G. Brown

Length of specimen, L 6.50 cm Diameter of specimen, D 6.4 cm

Tested by Ben Pitchford Date 2-8-05

Volume of specimen, $V = \frac{\pi}{4}D^2L$ (cm^2)	209.1
Specific gravity of soil solids, G_s	2.67
Mass of specimen tube with fittings, W_1 (g)	1460.46
Mass of tube with fittings and specimen, W_2 (g)	1795.96
Dry density of specimen, $\rho_d = \frac{W_2 - W_1}{V}$ (g / cm^3)	1.605
Void ratio of specimen, $e = \frac{G_s\rho_w}{\rho_d} - 1$ (*Note:* ρ_w = 1 g/cm^3)	0.664

Falling Head Permeability Test
Determination of Coefficient of Permeability

Test No.	1	2	3
Diameter of specimen, D (cm)	6.40	6.40	6.40
Length of specimen, L (cm)	5.20	5.20	5.20
Area of specimen, A (cm^2)	32.17	32.17	32.17
Beginning head difference, h_1 (cm)	119.4	119.4	119.4
Ending head difference, h_2 (cm)	118.7	118.5	118.6
Test duration, t (s)	900	960	1216
Volume of water flow through the specimen, V_w (cm^3)	1.2	1.4	1.3
$k = \frac{2.303V_wL}{(h_1 - h_2)tA}\log\frac{h_1}{h_2}$ (cm / s^2)	1.71(10^{-6})	2.06(10^{-6})	1.45(10^{-6})
Average k = 1.74(10^{-6}) cm/s			
$k_{20°C} = k_{T°C}\frac{\eta_{T°C}}{\eta_{20°C}}$ = N/A = ______ cm/s			

Falling Head Permeability Test
Determination of Void Ratio of Specimen

Description of soil Fine Sand Sample No. 002

Location G. G. Brown

Length of specimen, L 5.20 cm Diameter of specimen, D 6.4 cm

Tested by ______ Date 2-8-05

Volume of specimen, $V = \frac{\pi}{4}D^2L$ (cm^2)	167.28
Specific gravity of soil solids, G_s	2.71
Mass of specimen tube with fittings, W_1 (g)	1462.63
Mass of tube with fittings and specimen, W_2 (g)	1763.13
Dry density of specimen, $\rho_d = \frac{W_2 - W_1}{V}$ (g / cm^3)	1.796
Void ratio of specimen, $e = \frac{G_s\rho_w}{\rho_d} - 1$ (*Note:* ρ_w = 1 g/cm^3)	0.509

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APPENDIX D: CLASSIFICATION & SEEPAGE CALCULATIONS

Coarse Sand Classification

$\mathbf{C_u} = D_{60} / D_{10} = 0.53\text{mm} / 0.13\text{mm} = \mathbf{4.08 < 6}$

$\mathbf{C_c} = (D_{60})^2 / D_{10} D_{60} = 0.24^2 / (0.53)(0.13) = \mathbf{0.84 < 1}$

Thus, SP - Poorly Graded Sand

Fine Sand Classification

LL = 31 < 50

PI = 15 > 7

Using ASTM standards, the soil is a sand with more than 12% fines, and the fines are classified with the above LL and PI as CL - Lean Clay.

Thus, SC - Clayey Sand

Seepage

$\mathbf{Q = k\ H\ (N_f / N_d)\ (1')}$

N_f = Number of flow channels
N_d = Number of drops
k = Coefficient of permeability
H = Total head drop

$k_{fine} = 1.74\ (10^{-6})$ cm/s = $5.71\ (10^{-8})$ ft/s

H = 100 ft

Design #1

$Q = 5.71\ (10^{-8})$ ft/s (100 ft) (5/9) (1ft)

$Q = 3.17\ (10^{-6})\ \text{ft}^3/\text{s} = \mathbf{0.274\ ft^3/day}$

Design #2

$Q = 5.71\ (10^{-8})$ ft/s (100 ft) (5/15) (1ft)

$Q = 1.90\ (10^{-6})\ \text{ft}^3/\text{s} = \mathbf{0.164\ ft^3/day}$

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