GG Brown and Associates

800 Hayward Street
Ann Arbor, MI 48109

To: G.G. Brown, Engineering Manager

Subject: Results of relative density testing for Piper Associates' foundation of punch presses.

Date: September 20, 2007

I have completed the compaction and Atterburg limit tests on the Gold Art Clay for Piper Associates. The ASTM soil classification of the clay, Atterburg limits, maximum dry density and optimal water content have all been determined. I have attached my report for your review prior to mailing to Piper. If you have any questions or concerns please feel free to contact me at XXX.

Attachments: Letter Report to Piper Associates

GG Brown and Associates
800 Hayward Street
Ann Arbor, MI 48109

September 20, 2007

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

Re: **Relative density testing for foundation soil of punch presses.**

Dear Mr. Piper,

1.0 SUMMARY

GG Brown and Associates have performed compaction and Atterburg limit tests on the Gold Art Clay as requested. Tests were performed in general accordance with ASTM D-698-07e1. The Proctor test was used to determine the compaction curve. It was determined that the maximum dry density for Gold Art Clay is 110.6 pcf. The Atterburg Limits of liquid limit is 39% and plastic limit is 25.3%. The optimal water content is 15%. The clay was classified as CL in the group of leen clay.

2.0 INTRODUCTION

A letter dated October 16, 2007 from William Piper Associates, requested GG Brown and Associates determine group symbol and name for Gold Art Clay as well as the Atterburg Limits, the optimum water content and the maximum dry density. We have completed testing on November 6, 2007 using the Protector Test to determine the compaction curve of the soil of interest and therefore to determine the maximum dry density and the optimal water content as well as Atterburg limit tests to determine the Atterburg limits of the soil.

3.0 TEST SITE AND SOIL DESCRIPTION

The soil was previously sent to G.G. Brown Associates. The soil is the Gold Art Clay.

4.0 METHODOLOGY AND TEST PROCEDURES

The Compaction Test (proctor test) was used to determine the maximum dry unit weight and the optimal weight and was tested according to the following;
ASTM D698-07e1: *Standard Test Methods for Laboratory Compaction Characteristics of soil using Standard Effort*

The Atterburg Limits were found and tested according to the following:
ASTM D 4318-05: *Standard Test Methods for Liquid Limit. Plastic Limit and Plasticity Index of Soils.*

The Proctor test was performed to determine the compaction curve for a soil of interest, to include the determination of the maximum dry unit weight and the optimal water content for the Gold Art Clay. Mechanical compaction is the most common and effective way of stabilizing soil and prior to compaction in the field; the compaction characteristics should be tested and determined.

The Atterburg Limits Tests were performed to determine the liquid limit and the plastic limits of the soil. The water contents separating the transition from a semi solid state to a plastic and a plastic to a semi liquid state are called the plastic limit and the liquid limit respectively. The water content in soil significantly influences its behavior. And the difference between the liquid limit and the plastic limit is an indicator of potential problems

The detailed procedures for both tests can be found in Appendix A of this report.

5.0 DATA RESULTS AND ANALYSIS

The group symbol and group name were determined to be CL and leen clay respectively. This is because the PI is greater than 7.

The Atterburg limits were determined to be the following:

Liquid Limit = 39%
Plastic Limit = 25.3%

These values calculated from our test results, a full table of data results is included in Appendix B.

The Plastic Limit corresponds to the water content at which the soil will begin to crack when rolled out into a diameter of 3mm.

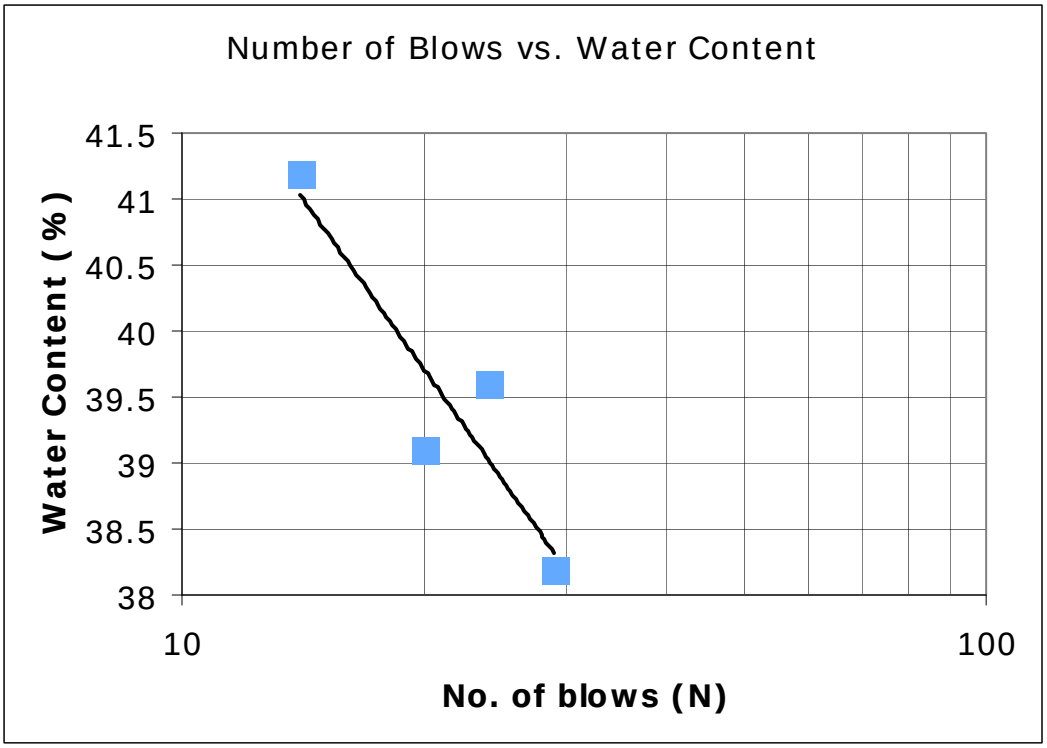
The liquid limit was calculated by comparing the number of blows to the water content. Table 1 summarizes the data. The liquid limit corresponds to the water content at 25 blows.

Table 1: Liquid Limit Calculation

Water Content (%)	Number of Blows (N)
38.2	29
39.1	20
39.6	24
41.2	14

From this table, the data can be plotted and seen in Graph 1. From this graph, a trend can be seen. As the water content increases, the number of blows to bridge the gap in the test decreases.

Graph 1: Number of Blows versus Water Content (LL determination)



The maximum dry density and optimal water content were to be the following:

Max Dry Density (γ_{dmax}) = 110.6 pcf
Optimal Water Content (ω_{opt}) = 15%

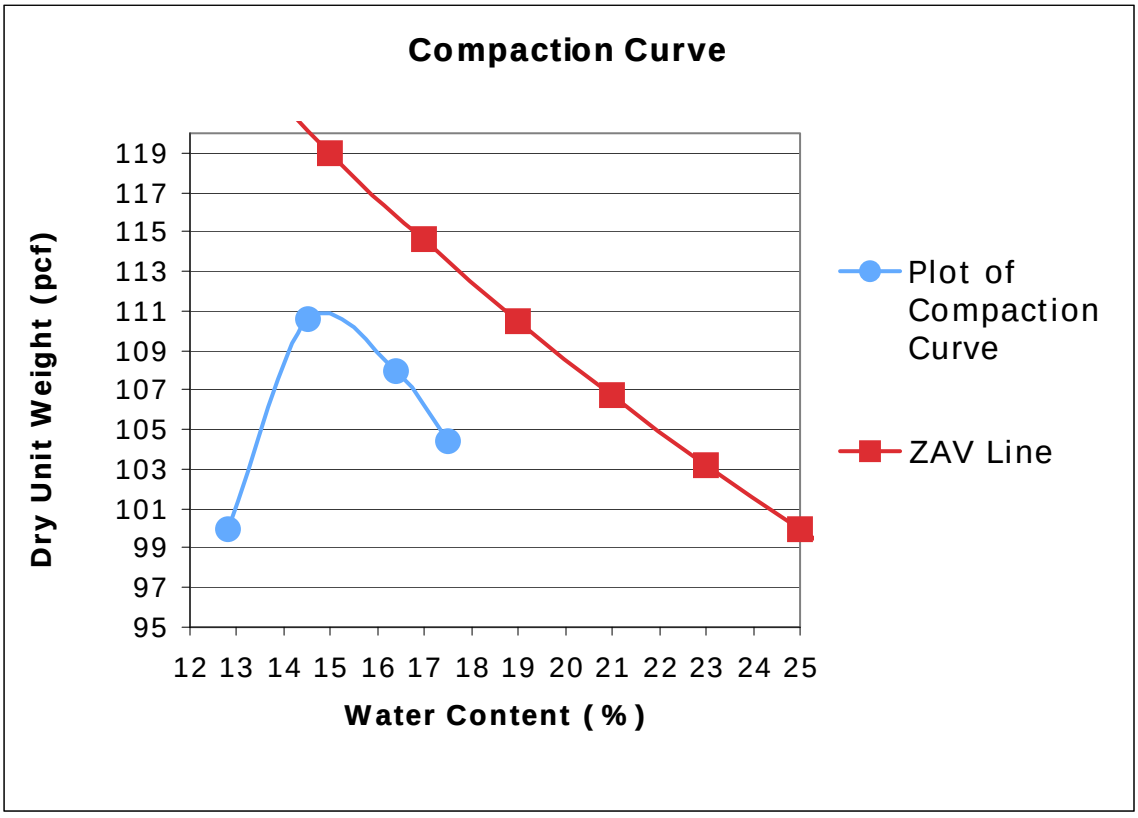
Table 2: Dry Unit Weights at Ranging Water Contents

Dry Unit Weight (pcf)	Average Water Content (%)
100	12.8
110.6	14.5
108	16.4
104.4	17.5
131.5	6

** Please note that the values from the 5th test were disregarded as the can plus dry soil weight exceeded that of the can plus wet soil. This is most likely the result of human error, possible an extra chunk of soil could have fallen in to the can in the process of conducting the lab.

When the data from Table 2 is plotted against each other along with the Zero Air Voids line, the compaction curve can be found as in Graph 2.

Graph 2: Compaction Curve



From this graph it is clear where the maximum water content and dry unit weights are obtained.

These values calculated from our test results, a full table of data results is included in Appendix C. From the results found in the laboratory, the optimum moisture content is lower in comparison to that of the empirical correlation (about 18%) provided in Figure 1 of Appendix E. This could be because of the fact that some of the moisture was lost while conducting the experiment. However the values are very similar as they were only about 3% away from each other. See Appendix E.

Sample calculations form both tests are included in Appendix D.

6.0 CONCLUSIONS AND RECCOMENDATIONS

Using the Proctor Test, the Max Dry Density was determined to be 110.6 pcf and the Optimal Water Content was determined to be 15%. The ASTM soil symbol and group name was determined to be CL and leen clay, respectively.

From the laboratory determined optimal water content that was found, it is determined that it is only slightly lower in comparison to the empirical correlation provided in Figure 1 of Appendix E. The empirical relation estimates that the optimal water content (based on the values of the liquid limit and the plastic limit) is about 18%, where as that found in the laboratory was 15%.

From the Atterburg Limit test the liquid limit was determined to be 39% and the plastic limit was determined to be 25.3%.

We have appreciated the opportunity to work with you and will be happy to discuss the results and possible recommendations of this testing or any other engineering need you may have. If you have any questions regarding this report please feel free to contact me at xxx@umich.edu.

Sincerely,

Engineering Manager

Appendices

Appendix A: Test Procedures

Appendix B: Data Sheet for Compaction Test

Appendix C: Data Sheet for Atterburg Limit Tests

Appendix D: Sample Calculations

Appendix E: Empirical Correlation Between Water Content and Atterburg Limits

Appendix D:

***Sample calculation of water content*:**

Test number 1 (*top*)

$$\frac{74.74 - 71.81}{71.81 - 49.6}(100\%) = 13.2$$

***Sample Calculation of Moist Unit Weight*:**

Test number 1

$$c = \frac{(W_2 - W_1)\,lb}{1/30\ ft^3} = \frac{13.01 - 9.25}{1/30} = 112.8\ pcf$$

***Sample Calculation of Dry Unit Weight*:**

Test number 1

$$c_d = \frac{112.8}{1 + \frac{12.8\%}{100}} = 100$$

To plot Zero Air Voids Line:

Let $S = 100\%$ *and* $G_s = 2.67$

Use the following equation:

$$c = \frac{G_s c_w}{1 + \frac{G_s w\%}{S}}$$