JOINT TRANSPORTATION RESEARCH PROGRAM

INDIANA DEPARTMENT OF TRANSPORTATION
AND PURDUE UNIVERSITY

JTRP

PROJECT IMPLEMENTATION: CLASSIFICATION OF ORGANIC SOILS AND CLASSIFCATION OF MARLS—TRAINING OF INDOT PERSONNEL

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SPR-3517
Report Number: FHWA/IN/JTRP-2012/22
DOI: 10.5703/1288284314984

RECOMMENDED CITATION

El Howayek, A., A. Bobet, S. Dawood, A. Ferdon, M. Santagata, and N. Z. Siddiki. *Project Implementation: Classification of Organic Soils and Classification of Marls—Training of INDOT Personnel*. Publication FHWA/IN/JTRP-2012/22. Joint Transportation Research Program, Indiana Department of Transportation and Purdue University, West Lafayette, Indiana, 2012. doi: 10.5703/1288284314984.

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JOINT TRANSPORTATION RESEARCH PROGRAM

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NOTICE

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No. FHWA/IN/JTRP-2012/22	**2. Government Accession No.**	**3. Recipient's Catalog No.**
4. Title and Subtitle Project Implementation: Classification of Organic Soils and Classification of Marls—Training of INDOT Personnel		**5. Report Date** September 2012 **6. Performing Organization Code**
7. Author(s) Alain El Howayek , Antonio Bobet , Sulaiman Dawood , Andrew Ferdon , Marika Santagata , Nayyar Siddiki		**8. Performing Organization Report No.** FHWA/IN/JTRP-2012/22
9. Performing Organization Name and Address Joint Transportation Research Program Purdue University 550 Stadium Mall Drive West Lafayette, IN 47907-2051		**10. Work Unit No.** **11. Contract or Grant No.** SPR-3517
12. Sponsoring Agency Name and Address Indiana Department of Transportation State Office Building 100 North Senate Avenue Indianapolis, IN 46204		**13. Type of Report and Period Covered** Final Report **14. Sponsoring Agency Code**

15. Supplementary Notes

Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration.

16. Abstract

This is an implementation project for the research completed as part of the following projects: SPR-3005 - Classification of Organic Soils and SPR-3227 – Classification of Marl Soils. The methods developed for the classification of both soils have been incorporated in INDOT standard specification 903.05 and 903.06 respectively. Both projects included recommendations for implementation that reflected input from the project PA and SAC. A specific recommendation from both projects was that INDOT soil technicians be trained to perform the required tests and classify soils based on the revised classification systems. This project was initiated to carry out the implementation of those recommendations.

The project scope includes development of training material for instruction about the performance of the revised classification tests and methods, training to pertinent INDOT personnel, integration of the revised classification system into INDOT’s standards, and establishment of a resource database for future training of INDOT personnel.

Within the general scope outlined above, the specific objectives of the proposed work were to: a) administer training to select INDOT personnel and interested representatives from the geotechnical consulting/construction community; b) develop training materials to be used by INDOT to train additional personnel. These two general objectives were accomplished through four specific tasks: 1) Collection of Sample Soils for Testing and Classification; 2) Development of Training Material (a PowerPoint presentation with concise instructional handouts; supporting classification examples from a variety of soils; and a short manual summarizing the classification system for both soils with supporting examples); 3) Delivery of Training Sessions for INDOT personnel, as well as representatives from select geotechnical consultants and contractors; 4) Production of Training Video.

17. Key Words organic soils, marls, identification, classification, training program	**18. Distribution Statement** No restrictions. This document is available to the public through the National Technical Information Service, Springfield, VA 22161.

19. Security Classif. (of this report)	**20. Security Classif. (of this page)**	**21. No. of Pages**	**22. Price**
Unclassified	Unclassified	126	

Form DOT F 1700.7 (8-69)

EXECUTIVE SUMMARY

PROJECT IMPLEMENTATION: CLASSIFICATION OF ORGANIC SOILS AND CLASSIFICATION OF MARLS—TRAINING OF INDOT PERSONNEL

Introduction

This is an implementation project for the research completed as part of two projects: SPR-3005, Classification of Organic Soils, and SPR-3227, Classification of Marl Soils. The methods developed for the classification of both soils have been incorporated in Indiana Department of Transportation (INDOT) standard specifications 903.05 and 903.06, respectively. Both projects included recommendations for implementation that reflected input from the project administrator and study advisory committee. A specific recommendation from both projects was that INDOT soil technicians be trained to perform the required tests and to classify soils based on the revised classification systems. This project was initiated to carry out the implementation of those recommendations.

The project scope includes developing training materials, training pertinent INDOT personnel, integrating the revised classification system into INDOT's standards, and establishing a resource database for future training of INDOT personnel.

Findings

- The presence of organics in soils can create problems in geotechnical practice by increasing the soil's compressibility and creep potential, decreasing its maximum dry density and strength, and potentially interfering with the soil's stabilization or modification with cement, lime, and cement or lime byproducts.
- Such problems are recognized in current INDOT specifications, which have strict limits on the percentage of organic matter allowed for certain applications. Thus, identification of organic soils and quantification of the percentage of organic matter is critical in many engineering projects. The method that was previously employed by INDOT to determine organic content tends to overestimate the percentage of organic matter. This is problematic because misclassification of organic soils can lead to significant costs that could be avoided.
- Marls typically have low dry density, very high moisture content, and low shear strength. As a result, they are considered problem soils and their correct identification and classification is critical in geotechnical engineering practice.
- Because of the generally unsatisfactory geotechnical properties of marls, INDOT specifications restrict the amount of calcium and magnesium carbonate that can be present in soils for a number of applications, similarly to how they restrict the presence of organic matter. The methodologies that are available for determining the calcium carbonate content are either very complex (e.g., the chemical determination of $CaCO_3$), or not sufficiently sensitive (e.g., the effervescent action of hydrochloric acid on the carbonate). As with organic soils, misclassification of marl soils can be costly.
- As a result, classification systems were developed to classify organics soils (SPR-3005) and marls (SPR-3227) more accurately and in a relatively easy manner.
- This project: (1) administers training to INDOT personnel and interested representatives from the geotechnical consulting/construction community, and (2) develops training materials to be used by INDOT to train additional personnel.

Implementation

This project was implemented based on four specific tasks:

1. Collection of sample soils for testing and classification.
2. Development of training material, namely: a PowerPoint presentation with concise instructional handouts; supporting classification examples for a variety of soils; and a manual summarizing the classification system for both soils with supporting examples.
3. Delivery of training sessions to INDOT personnel, as well as representatives from select geotechnical consulting firms and contractors.
4. Production of a training video.

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1. INTRODUCTION: BACKGROUND AND SCOPE

This is an implementation project for the research completed as part of two projects: SPR-3005, Classification of Organic Soils, and SPR-3227, Classification of Marl Soils. The methods developed for the classification of both soils have been incorporated in INDOT standard specification 903.05 and 903.06 respectively.

SPR-3005 addressed the classification of organic soils and the quantification of organic matter in soils. The study was motivated by the realization that the methods previously employed by INDOT to quantify organic matter content and the strict guidelines on organic content used to determine the acceptability of a soil for a given application could lead to incorrect classification of soils. This, in turn, could lead to erroneously considering a material unviable for a given application, and to unnecessary costs for material replacement/treatment.

The research conducted as part of SPR-3005 involved two main work streams: a review of the literature and a focused experimental effort. The former reviewed existing classification systems for organic soils, the effects of organic matter on the geotechnical properties of soils, and the methods for determination of organic content. The experimental component of the research involved performing loss on ignition tests, Atterberg limits, colorimetric tests, dry combustion tests, thermal analyses, and X-ray diffraction analyses on natural soils with varying organic content, as well as on laboratory prepared ("artificial") organic soils.

The work led to the proposition of a revised system for classifying soils in four groups (peats; organic soils; mineral soils with organic matter; and mineral soils) based on the percentage of organic matter estimated from the loss on ignition (LOI) in combination with the liquid limit ratio and the results of the colorimetric test. These methods were validated with tests on a variety of soils. It was found that based on the LOI results, some soils that might be considered unviable for roadway construction, did not instead contain significant amounts of organics. These observations were supported by in-laboratory chemical measurements.

SPR-3227 addressed the classification of marl soils—soft, carbonate-rich, low-organic, light gray colored clay or silt deposits (*fine-grained soils only*) that are formed by precipitation of calcite below an organic soil deposit. Marly soils, which are also often characterized by the presence of organic matter (4–20%), are not generally well described with existing soil classification systems, and the methodologies available for their identification in the laboratory or in the field are either not adequate or not effective. To address this, the project involved testing of marl samples obtained from three INDOT road construction projects. The experimental program included determinations of the $CaCO_3$ percentage using three different approaches (chemically; through thermogravimetric analysis (TGA); and through a "sequential" loss on ignition (LOI) test), as well as XRD analyses, pH tests, and Atterberg limit tests.

The experimental work: (a) re-endorsed the classification previously used by INDOT that classifies soils into five groups based on the % of $CaCO_3$ ("soil with trace of marl"; "soil with little marl"; "soil with some marl"; "marly soil"; "marl"); (b) validated the use of any of the methods above for measuring the % of $CaCO_3$ (with the sequential LOI test having the advantage of also providing an estimate of the organic content); and (c) proposed a simple classification procedure to identify a marl soil in the field, based on the color of the dry soil and its reaction with a 1M HCL solution.

Both SPR-3005 and SPR-3227 included recommendations for implementation that reflected input from the project administrator (PA) and study advisory committee (SAC). A specific recommendation from both projects was that INDOT soil technicians be trained to perform the required tests and classify soils based on the revised classification systems.

This project was initiated to carry out the implementation of those recommendations. The project scope includes development of training material for instruction in performance of the revised classification tests and methods, delivery of that training to pertinent INDOT personnel, integration of the revised classification system into INDOT's standards (specifications 903.05 and 903.06), and establishment of a resource database for future training of personnel.

2. PROJECT OBJECTIVES

Within the general scope outlined above, the specific objectives of the proposed work are to:

1. Administer training to select INDOT personnel and interested representatives from the geotechnical consulting/construction community.
2. Develop training materials to be used by INDOT to train additional personnel.

3. PROJECT TASKS

The two objectives outlined above were accomplished through the completion of four specific tasks.

Task 1: Collection of Sample Soils for Testing and Classification

Task Description

Demonstration of the classification method and testing procedures required that several sample soils be obtained from different locations around Indiana. Thus, a small collection program was necessary to acquire the needed samples.

Task Completion

The first task for this project was to identify/test reference soils to be used as supporting classification examples. Specifically, efforts focused on finding reference soils with different percentages of organics and calcium carbonate that fell in the following categories:

1. 1 to 2 organic soils with no $CaCO_3$
2. 1 to 2 marly soils with no organics
3. 1 to 2 soils with both organics and $CaCO_3$ (critical to examine the combined use of the two classification systems)
4. 1 mineral soil
5. 1 soil that provided a false positive to the presence of organics based on the LOI test

In order to collect information on site locations that may have organic and/or marl soils with the characteristics listed above, fact-finding interviews were conducted with a number of persons, including INDOT personnel, private contractors, and consultants: Tom Coffey (Alt & Witzing Engineering); Michael Wigger and Darren Pleiman (Earth Exploration Inc.); Shawn Marcum (ATC Associates); Firooz Zandi (K&S Engineers Inc.); Radha Daita (H.C. Nutting, Terracon Co.); and Joey Franzino, Jonathan Paauwe and Youlanda Belew (INDOT). As a result of these efforts, samples were obtained from three different sources (Figures 3.1 through 3.3). From 12 samples tested, 7 were chosen to be used as reference soils for supporting classification examples (Table 3.1).

Additional samples were taken from a fourth site, part of section 3, segment 13 (Daviess, Indiana) of I-69, in conjunction with another currently ongoing JTRP Project (SPR-3639, Engineering Properties of Marls). Details on the sampling operations are provided in the report for that project.

Task 2: Development of Training Material

Task Description

Materials were to be developed providing adequate instruction in both the revised classification system (for organic and marl soils) and the testing methods necessary to perform the classification. The training material was to be designed in such a manner as to be conducive to administration in a small “classroom” setting, with a target training time of approximately 3 hours. Specifically, the materials were to include:

1. A PowerPoint presentation supported by concise instructional handouts.
2. Supporting classification examples for a variety of soils.
3. A short manual summarizing the classification system for both soils with supporting examples.

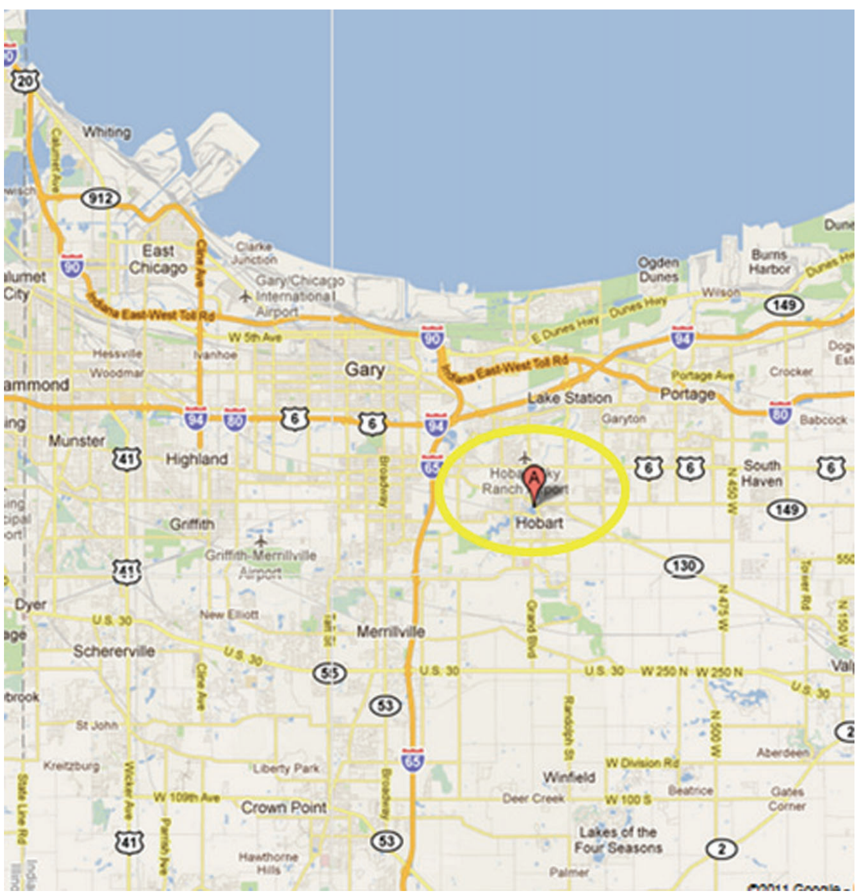

Figure 3.1 Sample source 1.

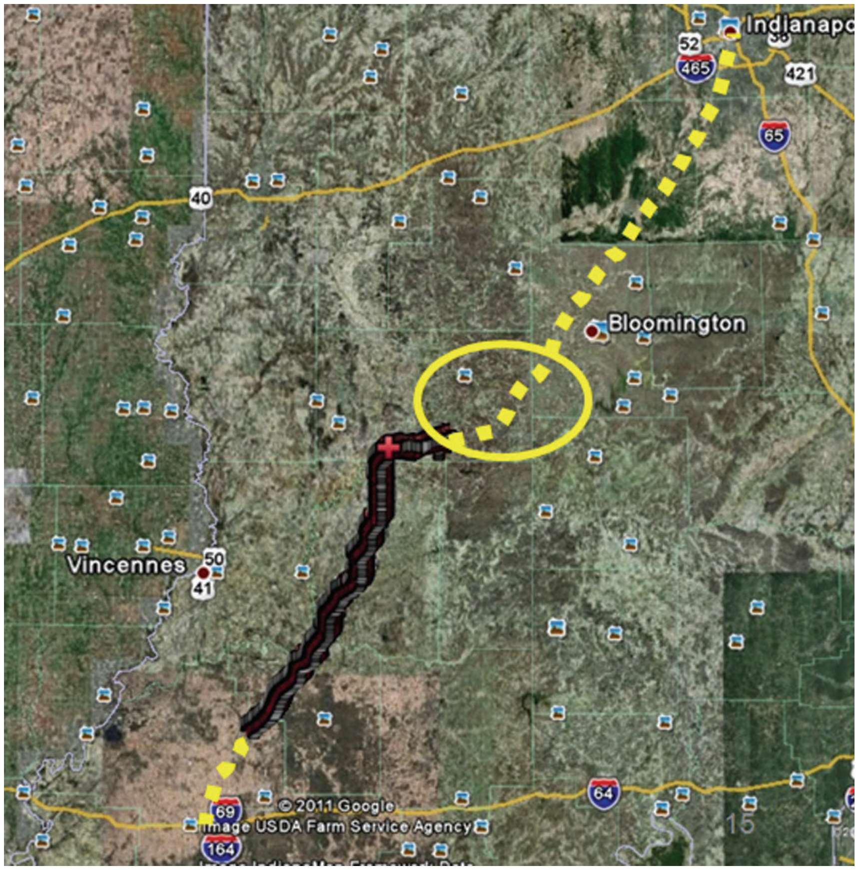

Figure 3.2 Sample source 2.

In addition to the hard copies provided to INDOT, digital copies of the aforementioned materials were to be uploaded to an internet repository for future access by INDOT personnel. The repository was also to include results from testing/classification of sample soils.

Task Completion

The following items were developed for the purpose of training INDOT personnel in the revised classification systems (for organic and marl soils) and the associated tests required for classifications. Copies of these items are included in the appendices of this report.

- ***PowerPoint Presentation***—The presentation (Appendix 1) contains a short background section, which describes the need for a revised classification system for both organics and marls. The rest of the presentation is divided into "organic," "marl," and "combined" sections, which describe the required tests (LOI, colorimetric, and LLR for organic soils; sequential LOI for marls), outline the respective classification procedure, and present classification examples (using some the sample soils presented in Table 3.1).
- ***Lab Manual***—A short manual was compiled (Appendix 2) that summarizes the objectives, procedures, and results from SPR-3005 and SPR-3227. The manual includes references for further inquiry.
- ***Short Procedure for Identification and Classification of Organic Soils***—This document (Appendix 3) outlines the references, scope, apparatus, procedure, calculations, and report required for performance of the tests necessary for classification of organic soils (LOI, colorimetric, and LLR). It also includes sample data sheets for each of the tests.
- ***Short Procedure for Identification and Classification of Marly Soils***—This document (Appendix 4) outlines the references, scope, apparatus, procedure, calculations, and report required for performance of the test necessary for classification of marly soils (sequential LOI). It also includes sample data sheets for the test.
- ***Classification Charts***—These flowcharts (Appendix 5) demonstrate graphically the classification process for organic soils, marly soils, and combined (organic and marly) soils. They are necessary for the actual classification of soils (using the results from the tests in the *Short Procedure* above).
- ***Classification Checklists***—These checklists (Appendix 6) provide bullet point steps for classification of organic soils, marly soils, and combined soils. They are to be used in conjunction with the *Classification Charts* (Appendix 5) as a quick reference for the classification procedure.
- ***Supporting Classification Examples***—These items consist of sample data sheets (Appendix 7) with test results for the sample soils collected for demonstration of the testing procedure. They were designed to be used as accessory practice problems in the training sessions (see Task 3 below). However, they are also useful for classification practice, as the data sheets (containing raw data) can be used in conjunction with the PowerPoint presentation (containing the actual classification of the soils based on the data) for "self-study."

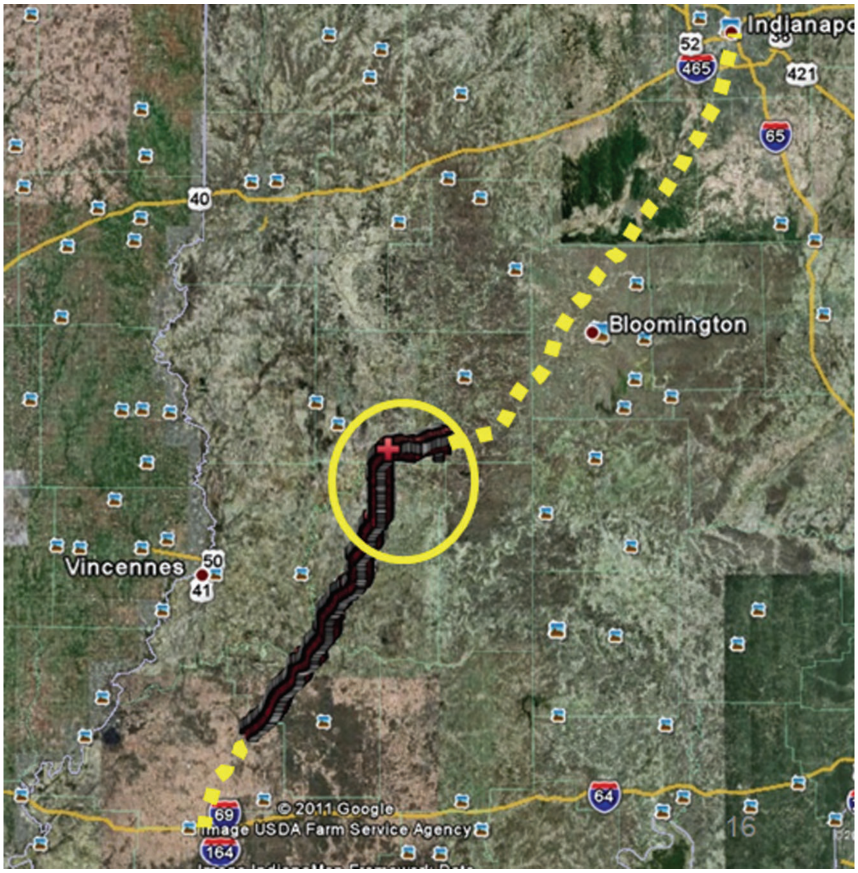

Figure 3.3 Sample source 3.

Task 3: Delivery of Training Sessions

Task Description

Training sessions were to cover the classification system and necessary testing methods, and to be administered to INDOT technicians, lab managers, geologists, engineers, and any other pertinent personnel, as well as representatives from select geotechnical consultants and contractors. Three to four sessions of approximately half a day (~4 hours) in length were to be held at several locations around the state, with the locations selected by INDOT.

Task Completion

A total of four training sessions were held at INDOT facilities around the state. First, a pilot session was held at INDOT′s Indianapolis Materials Tests facility, where the attendees were primarily engineering staff and testing lab managers. This served as a trial run for the subsequent training sessions. Feedback was collected for improving the PowerPoint presentation, the handouts, and the delivery.

The remaining sessions were held at the Seymour District Office (which included representatives from Seymour and Indianapolis), the LaPorte District Office

TABLE 3.1
Sample soils used as supporting classification examples

Soil #	Soil name	LOI (%)	$CaCO_3$ (%)	Source
1	"Soil with trace marl & organic matter"	8.0	2.4	Daviess, Indiana (EEI)
2	"Marl"	2.2	62.6	Daviess, Indiana (EEI)
3	"Soil with some marl"	2.4	21.1	Daviess, Indiana (EEI)
4	"Marly soil with organic matter"	7.3	26.2	Hobart, Indiana (EEI)
5	"Soil with some marl & organic matter"	6.8	23.9	Hobart, Indiana (EEI)
6	"Soil with trace marl"	2.3	3.2	Daviess, Indiana (EEI)
7	"Soil with trace marl—false positive"	3.6	4.7	ASTM CL

(which included representatives from LaPorte and Ft. Wayne), and finally at INDOT′s Indianapolis Materials Tests facility, which included representatives from Indianapolis, Greenfield, and several geotechnical consultants and contractors. A complete listing of dates, locations, attendees, and affiliations, is included as Appendix 8.

The training sessions were delivered by Alain El Howayek, MSCE. First, a short background was provided on the necessity for improved classification systems for both organic and marly soils. Next, the test procedures required for each classification system were described. The colorimetric test in particular was demonstrated at each location, as not all attendees were familiar with its procedure. Following description of the required tests, the classification systems themselves were outlined. Finally, classification examples were demonstrated using actual test data (from the collected samples).

Attendees were issued an information packet upon arrival at the training sessions. The packets contained printouts of the PowerPoint presentation, "short procedures," classification charts, classification checklists, and supporting example data sheets. A CD was also included within each packet, containing electronic copies of the aforementioned items, as well as a copy of the lab manual summarizing SPR-3005 and SPR-3227. Feedback was collected following each training session through anonymous response forms and was used to improve and refine the sessions that followed. A copy of the feedback form is included as Appendix 9.

Task 4: Production of Training Video

Task Description

A short training video was to be prepared covering the materials from the training presentation, such that interested INDOT personnel could independently learn the classification system and testing procedures through self-study. The video was to include classification examples and demonstrations of the required tests. A hard disc copy of the video was to be delivered to INDOT for usage as necessary.

Task Completion

A short training video was developed covering the materials from the training presentation, such that INDOT personnel could learn the classification system and testing procedures through self-study. The video has been uploaded to an online Joint Transportation Research Program repository at the following URL: http://dx.doi.org/10.5703/1288284315027. It includes a full description of the classification systems as well as examples and visual demonstrations of the required tests.

4. ACKNOWLEDGMENTS

This training program was developed as part of SPR-3517. The principal investigators were Professors Marika Santagata and Antonio Bobet of Purdue University, and Mr. Nayyar Zia Siddiki of INDOT's Geotechnical Office. A number of people contributed to this work. The classification procedures were developed as part of two previous JTRP projects by Mr. Pao Tsung Huang, for organic soils, and by Dr. Chul Min Jung, for marly soils. A team of Purdue students was responsible for developing all training material for this implementation project. The team was headed by Mr. Alain El Howayek, and included Mr. Sulaiman Dawood, Mr. Andrew Ferdon, Mr. Alex Sangermano (voice on the video), and Mr. Michael Stockwell. Several members of INDOT have contributed to this training program, in particular Mr. Athar Khan, Manager of INDOT's Geotechnical Services, and Mr. Brian Dunbar, Mr. Ron Fine, Mr. Iqbal Khan, Dr. Tommy Nantung, and Mr. Mike Nelson, who participated in the pilot training program, and provided feedback on this presentation.

5. CONCLUSIONS

This implementation project, SPR-3517, completed the proposed objectives. Training was successfully administered to INDOT personnel and interested representatives from the geotechnical consulting/construction community on the revised classification methods for organic and marly soils developed in SPR-3005 and SPR-3227. Training materials were developed for use by INDOT in future training.

The accessory tasks were also successfully completed. Training materials were uploaded to an online repository for easy access by INDOT personnel. The INDOT Geotechnical Manual was updated to include the classifications systems developed in SPR-3005 and SPR-3227. A training video was produced and made available to INDOT for usage in future training sessions, and soil samples were collected from around the state for demonstration of the classification system.

APPENDIX 1

PURDUE UNIVERSITY

TRAINING PROGRAM

Classification of Organic Soils & Classification of Marls

Developed for INDOT by Purdue University

Funded through Joint Transportation Research Program (SPR-3517)

WHY ARE WE HERE?

PURDUE UNIVERSITY

Background to Training Program

- 2008: Purdue study for INDOT on "Classification of Organic Soils"
  - funded through JTRP (SPR-3005)
  - report available http://docs.lib.purdue.edu/jtrp/1186/
- 2009: Purdue study for INDOT on "Classification of Marl Soils"
  - funded through JTRP (SPR-3227)
  - report available http://docs.lib.purdue.edu/jtrp/1144/
- 2011: To implement findings from above projects INDOT commissioned Purdue the development of a training program
  - Funded through JTRP (SPR-3517)

OUTLINE

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- ❑ MOTIVATION – WHY ARE WE HERE?
- ❑ OBJECTIVES & RESOURCES
- ❑ PROPOSED CLASSIFICATION METHODS
  - ❑ ORGANIC SOILS
  - ❑ MARLS
  - ❑ MARLY & ORGANIC SOILS
- ❑ SELF LEARNING EXAMPLES

WHAT IS SOIL ORGANIC MATTER?

PURDUE UNIVERSITY

"Soil Organic Matter"

"The organic fraction of soil, including plant, animal, and microbial residues, fresh and at all stages of decomposition…"

(Soil Science Society of America, 1979)

OUTLINE

PURDUE UNIVERSITY

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WHY ARE WE HERE?

PURDUE UNIVERSITY

The Presence of Organic Matter Can…

- Increase Soil Compressibility
- Increase Creep Potential
- Decrease Maximum Dry Density
- Decrease Soil Strength
- Interfere with Soil Stabilization/Modification

APPENDIX 1

WHY ARE WE HERE?

Significance of Problem – ORGANIC SOILS

- Current INDOT specifications have strict limits on % of organics allowed in subgrade soils and backfills
- Previously used methods can overestimate organic %
- Misclassification of organic soils can lead to costly operations of soil excavation/replacement

WHY ARE WE HERE?

- **Misclassification can be costly**

  *INDOT project in Porter County (2006-2007)**

  - Removal of **23,000 yd³ (17,500 m³)** of soil considered unsuitable for roadway construction
  - ***If*** soil excavation and replacement ***could have been*** avoided, this would have resulted in a saving of **$650,525**

* For illustration purposes only.
Soil data from this project was not available for development of this program

WHY ARE WE HERE?

- **INDOT Specifications**

"Soils containing greater than **3%** […] ***organic material***, or with a maximum dry density of less than 100 pcf [….] will not be permitted [in the **roadway subgrade**]"

(INDOT Standard Specification 207.03)

"Soils containing greater than **7%** […] ***organic material***, or with a maximum dry density of less than 90 pcf [….] will not be permitted in the **embankment**"

(INDOT Standard Specification 203.09)

WHAT ARE MARLS?

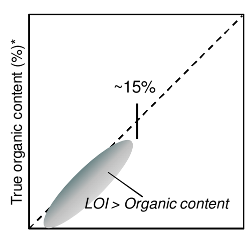
"Marls"

- Light gray, to almost white, fine-grained soil (silts and clays)
- Calcium Carbonate ($CaCO_3$) rich
- Formed by precipitation of calcite at the bottom of lakes or swamps
- Typically have: low dry density, very high moisture content, & low shear strength

WHY ARE WE HERE?

- **Problems with previously used methods**

  - The loss on ignition method can overestimate true organic content.
  - The error can be especially significant for values <15%



** based on dry oxidation test*

WHY ARE WE HERE?

Significance of Problem – MARL SOILS

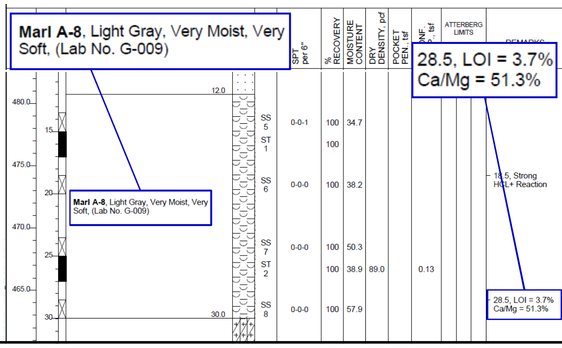
- Current INDOT specifications have strict limits on % of carbonates allowed in subgrade soils
- Calcium and magnesium carbonate are commonly found in soft, fine-grained soils called marls
- Methodologies available for marl identification are either complex (e.g. *chemical determination of $CaCO_3$) or not sufficiently sensitive (e.g. **HCl reaction)
- Misclassification of marl soils can be costly

*ASTM C25
**ASTM D4373

APPENDIX 1

WHY ARE WE HERE?

- **Carbonates commonly present in marls**



AASHTO CLASSIFICATION

Issues:

- AASHTO Classification is deficient when it comes to organic and marly soils
- "A-#" groups classification do not take into account the % of organic matter & carbonate content
- Highly organic soils & marls (included in group A-8) are classified based solely on visual inspection
- INDOT needs a classification terminology that provides information on organic & carbonate content, in addition to AASHTO soil type

WHY ARE WE HERE?

- **INDOT Specifications**

"Soils containing greater than **3%** […] ***calcium, magnesium carbonate***, or with a maximum dry density of less than 100 pcf [….] will not be permitted [in the **roadway subgrade**]"

(INDOT Standard Specification 207.03)

"Soils containing greater than **7%** […] ***calcium, magnesium carbonate***, or with a maximum dry density of less than 90 pcf [….] will not be permitted in the **embankment**"

(INDOT Standard Specification 203.09)

OUTLINE

- ❑ MOTIVATION – WHY ARE WE HERE?
- ❑ OBJECTIVES & RESOURCES
- ❑ PROPOSED CLASSIFICATION METHODS
  - ❑ ORGANIC SOILS
  - ❑ MARLS
  - ❑ MARLY & ORGANIC SOILS
- ❑ SELF LEARNING EXAMPLES

WHY ARE WE HERE?

Significance of Problem – MARL SOILS

- Current INDOT specifications have strict limits on % of carbonates allowed in subgrade soils
- Calcium and magnesium carbonate are commonly found in soft, fine-grained soils called marls
- Methodologies available for marl identification are either complex (e.g. *chemical determination of $CaCO_3$) or not sufficiently sensitive (e.g. **HCl reaction)
- Misclassification of marl soils can be costly

*ASTM C25
**ASTM D4373

WHAT WILL YOU LEARN?

- At the end of this presentation you will be able to:
  - Classify organic soils
  - Classify marly soils
  - Perform the laboratory procedures required for soil classification
  - Conduct the necessary calculations required for soil classification

APPENDIX 1

RESOURCES

PURDUE UNIVERSITY

- Resources associated with these videos:
  - Concise handouts with step-by-step classification procedures
  - A short manual for both organic soils and marls containing:
    - Literature review
    - Description of the proposed classification systems
    - Supporting classification examples

CLASSIFICATION OF ORGANICS

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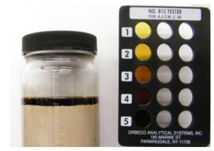
- This classification system is based on the combined results from three different tests, performed on specimens from same sample:

I. Loss on Ignition (LOI)

II. Colorimetric Test



III. Liquid Limit Ratio (LLR)

Organics | Marls | Combined

OUTLINE

PURDUE UNIVERSITY

- ❑ MOTIVATION – WHY ARE WE HERE?
- ❑ OBJECTIVES & RESOURCES
- ❑ **PROPOSED CLASSIFICATION METHODS**
  - ❑ **ORGANIC SOILS**
  - ❑ MARLS
  - ❑ MARLY & ORGANIC SOILS
- ❑ SELF LEARNING EXAMPLES

Organics | Marls | Combined

CLASSIFICATION OF ORGANICS

PURDUE UNIVERSITY

- A four tier-classification based on organic content (%)

Classification	Organic Content (%)
Mineral soils	OC ≤ 3%
Mineral soils with organics	3% < OC ≤ 15%
Organic soils	15% < OC ≤ 30%
Highly organic soils or peats	OC > 30%

Organics | Marls | Combined

CLASSIFICATION OF ORGANICS

PURDUE UNIVERSITY

- A four tier-classification based on organic content (%)

Classification	Organic Content (%)
Mineral soils*	OC ≤ 3%
Mineral soils* with organics	3% < OC ≤ 15%
Organic soils	15% < OC ≤ 30%
Highly organic soils or peats	OC > 30%

* "Mineral soils" designated through AASHTO terminology

Organics | Marls | Combined

CLASSIFICATION OF ORGANICS

PURDUE UNIVERSITY

- A four tier-classification based on organic content (%)

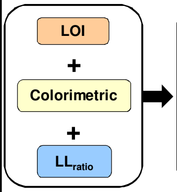
	Classification	Organic Content (%)
LOI ➡	**Mineral soils**	**OC ≤ 3%**
	Mineral soils with organics	3% < OC ≤ 15%
LOI ➡	**Organic soils**	**15% < OC ≤ 30%**
LOI ➡	**Highly organic soils or peats**	**OC > 30%**

Organics | Marls | Combined

APPENDIX 1

CLASSIFICATION OF ORGANICS

- A four tier-classification based on organic content (%)

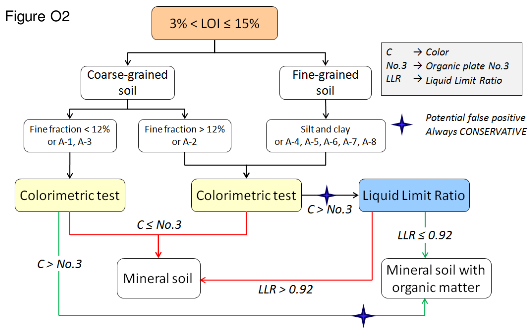


Classification	Organic Content (%)
Mineral soils	OC ≤ 3%
Mineral soils with organics	**3% < OC ≤ 15%**
Organic soils	15% < OC ≤ 30%
Highly organic soils or peats	OC > 30%

Organics Marls Combined

CLASSIFICATION OF ORGANICS

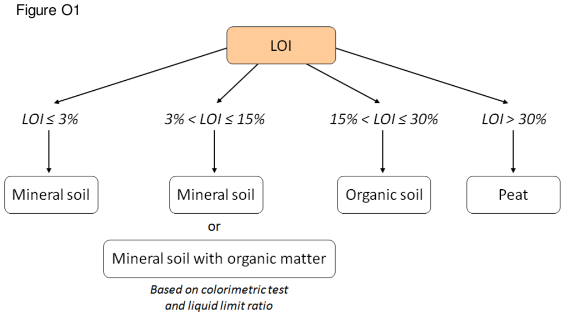
Figure O2



Organics Marls Combined

CLASSIFICATION OF ORGANICS

Figure O1

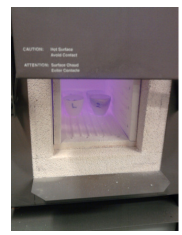


Organics Marls Combined

I. Loss on Ignition LOI

In brief….

Heat oven dried sample to 455°C and measure resulting mass loss



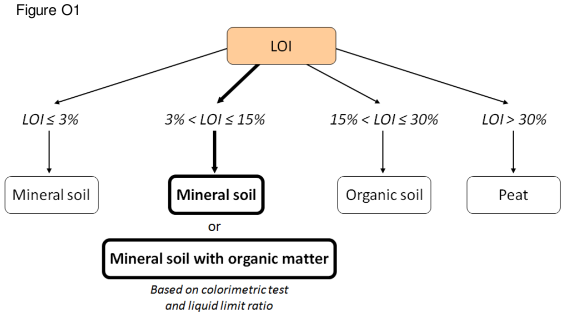
Standards:

(ASTM D2974 – 07a, AASHTO T267 – 86)

Organics Marls Combined

CLASSIFICATION OF ORGANICS

Figure O1



Organics Marls Combined

I. Loss on Ignition LOI

Premise

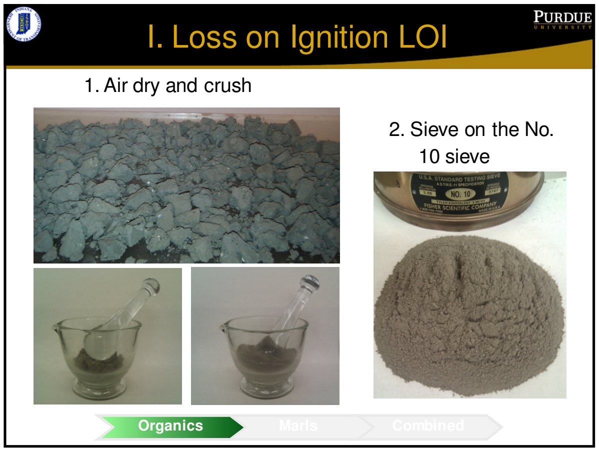
- organic matter is burnt by heating to 455°C

Concern

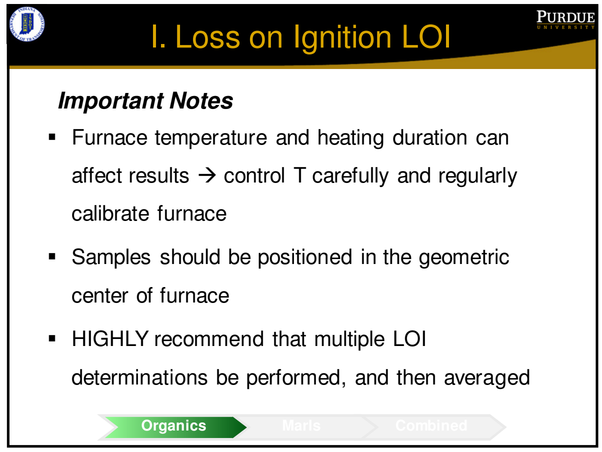
- other materials (e.g. some clay minerals) can also burn in this temperature range leading to overestimate organic content.

Organics Marls Combined

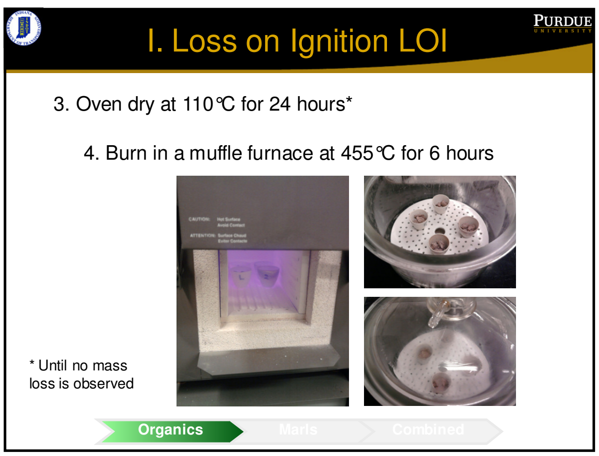
APPENDIX 1



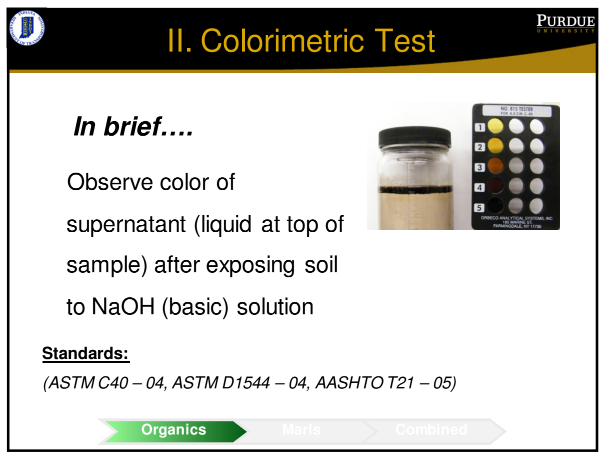
I. Loss on Ignition LOI
PURDUE
1. Air dry and crush
2. Sieve on the No. 10 sieve
Organics
Marls
Combined



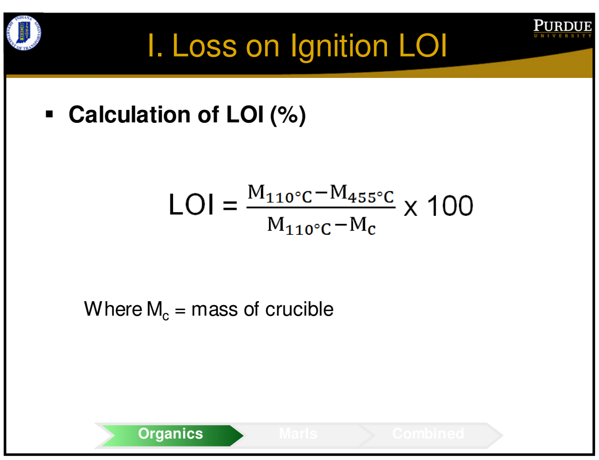
I. Loss on Ignition LOI
PURDUE
Important Notes
Furnace temperature and heating duration can affect results → control T carefully and regularly calibrate furnace
Samples should be positioned in the geometric center of furnace
HIGHLY recommend that multiple LOI determinations be performed, and then averaged
Organics
Marls
Combined



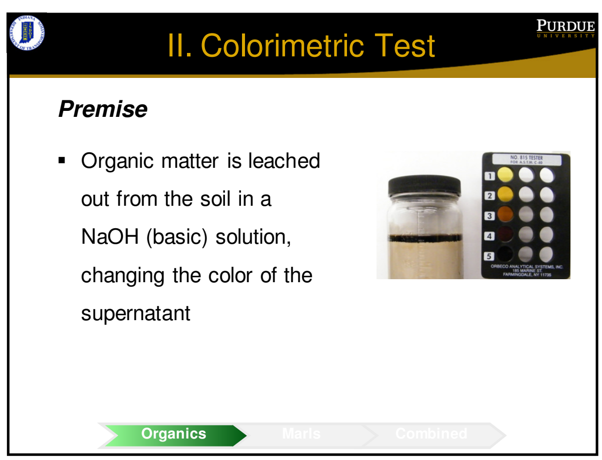
I. Loss on Ignition LOI
PURDUE
3. Oven dry at 110℃ for 24 hours*
4. Burn in a muffle furnace at 455℃ for 6 hours
* Until no mass loss is observed
Organics
Marls
Combined



II. Colorimetric Test
PURDUE
In brief….
Observe color of supernatant (liquid at top of sample) after exposing soil to NaOH (basic) solution
Standards:
(ASTM C40 – 04, ASTM D1544 – 04, AASHTO T21 – 05)
Organics
Marls
Combined

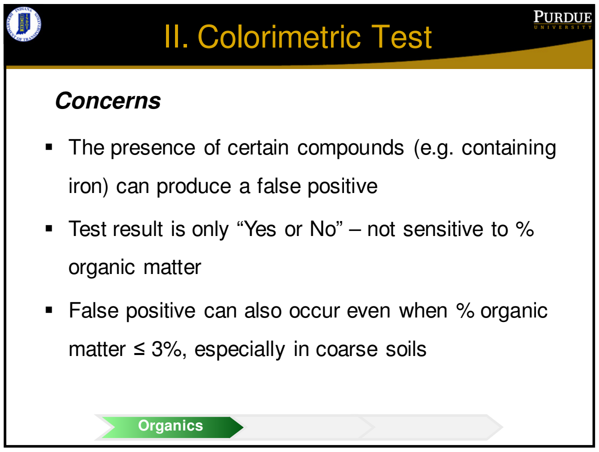


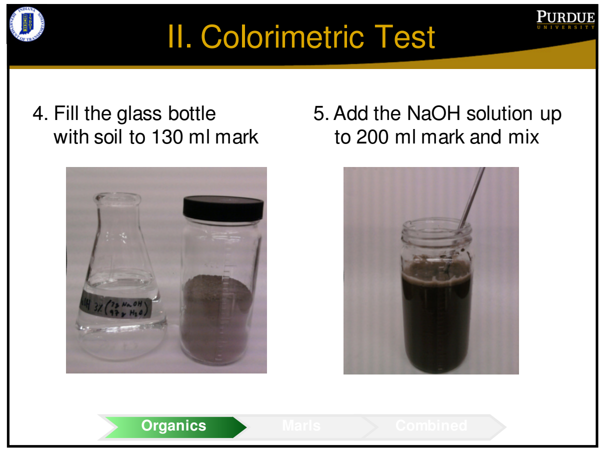
I. Loss on Ignition LOI
PURDUE
Calculation of LOI (%)
$LOI = \frac{M_{110°C} - M_{455°C}}{M_{110°C} - M_{c}} \times 100$
Where M_c = mass of crucible
Organics
Marls
Combined

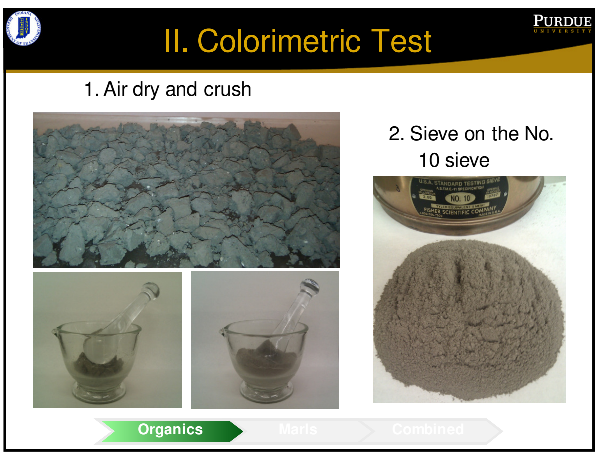


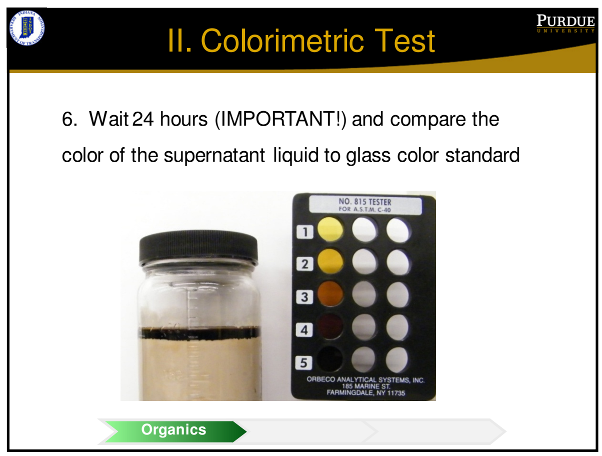
II. Colorimetric Test
PURDUE
Premise
Organic matter is leached out from the soil in a NaOH (basic) solution, changing the color of the supernatant
Organics
Marls
Combined

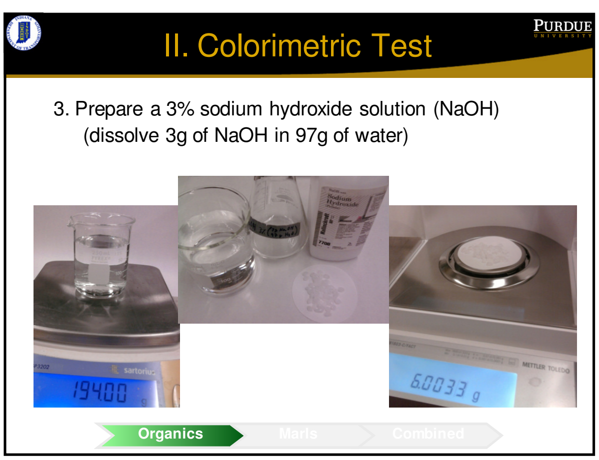
APPENDIX 1

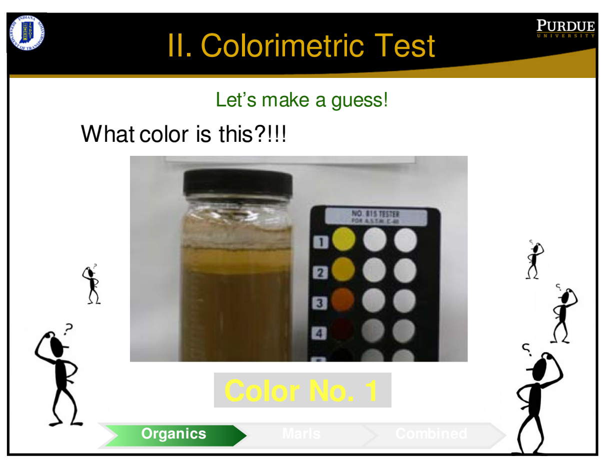

PURDUE
II. Colorimetric Test
Concerns
▪ The presence of certain compounds (e.g. containing iron) can produce a false positive
▪ Test result is only "Yes or No" – not sensitive to % organic matter
▪ False positive can also occur even when % organic matter ≤ 3%, especially in coarse soils
Organics


PURDUE
II. Colorimetric Test
4. Fill the glass bottle with soil to 130 ml mark
5. Add the NaOH solution up to 200 ml mark and mix
Organics
Marls
Combined

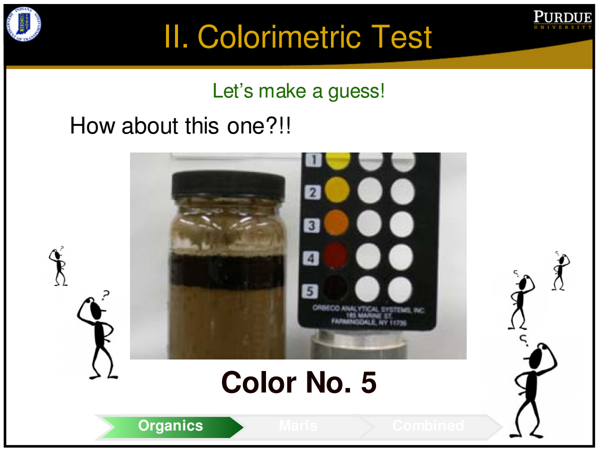

PURDUE
II. Colorimetric Test
1. Air dry and crush
2. Sieve on the No. 10 sieve
Organics
Marls
Combined

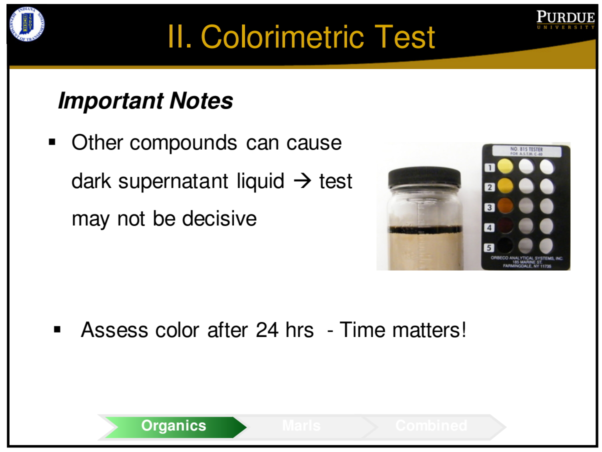

PURDUE
II. Colorimetric Test
6. Wait 24 hours (IMPORTANT!) and compare the color of the supernatant liquid to glass color standard
NO. 815 TESTER FOR A.S.T.M. C-40
1
2
3
4
5
ORBECO ANALYTICAL SYSTEMS, INC.
Organics

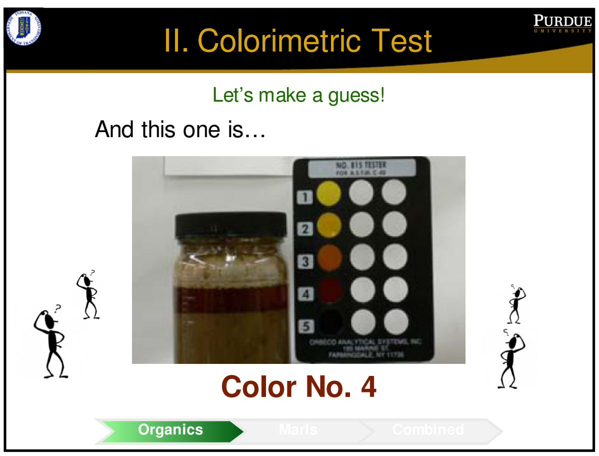

PURDUE
II. Colorimetric Test
3. Prepare a 3% sodium hydroxide solution (NaOH) (dissolve 3g of NaOH in 97g of water)
194.00
6.0033 g
Organics
Marls
Combined

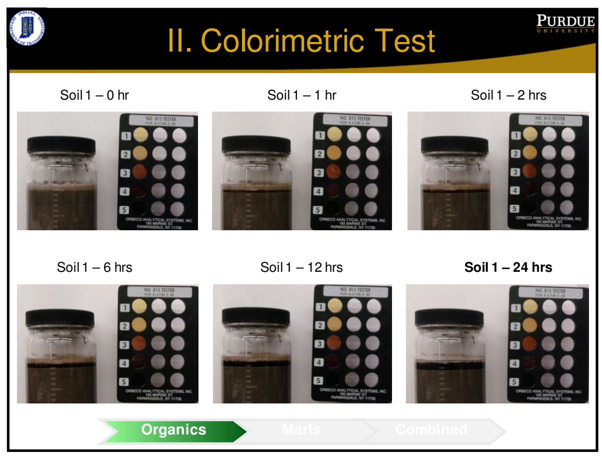

PURDUE
II. Colorimetric Test
Let's make a guess!
What color is this?!!!
Color No. 1
Organics
Marls
Combined

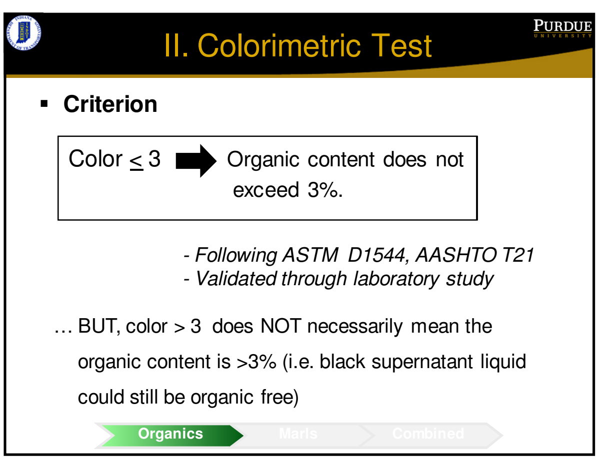
APPENDIX 1

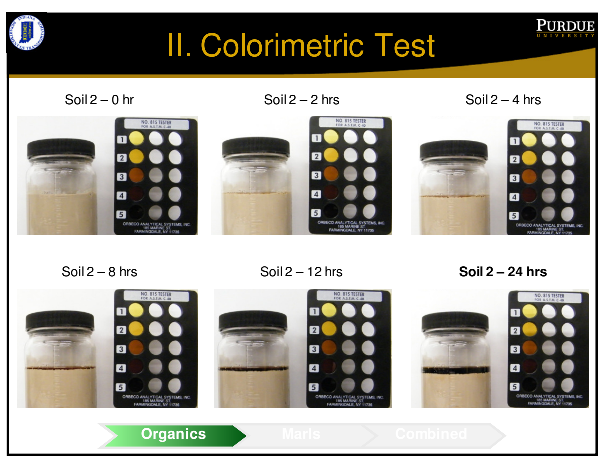

II. Colorimetric Test
PURDUE
Let's make a guess!
How about this one?!!
Color No. 5
Organics
Marls
Combined


II. Colorimetric Test
PURDUE
Important Notes
Other compounds can cause dark supernatant liquid → test may not be decisive
Assess color after 24 hrs - Time matters!
Organics
Marls
Combined

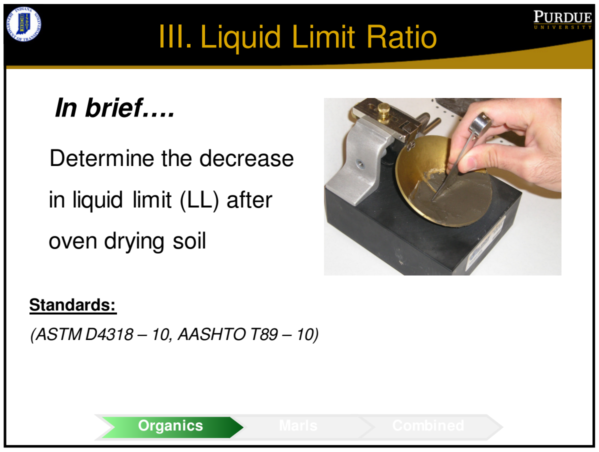

II. Colorimetric Test
PURDUE
Let's make a guess!
And this one is…
Color No. 4
Organics
Marls
Combined

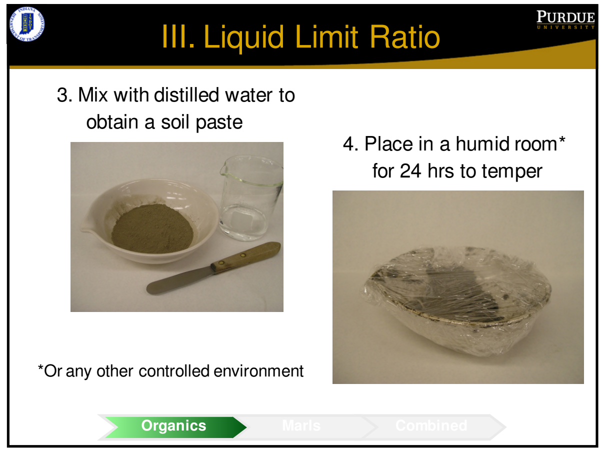

II. Colorimetric Test
PURDUE
Soil 1 – 0 hr
Soil 1 – 1 hr
Soil 1 – 2 hrs
Soil 1 – 6 hrs
Soil 1 – 12 hrs
Soil 1 – 24 hrs
Organics
Marls
Combined

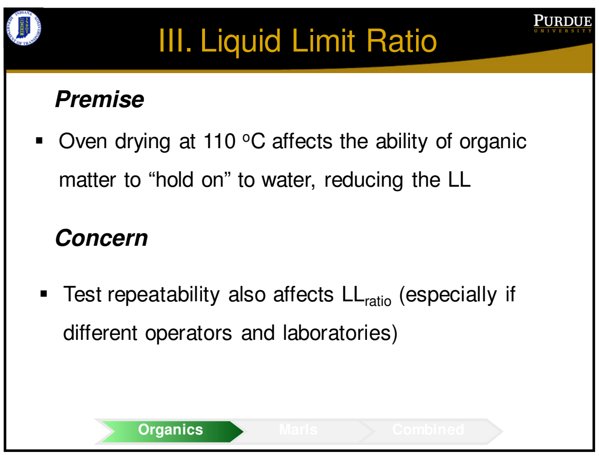

II. Colorimetric Test
PURDUE
Criterion
Color $\leq$ 3 ➡ Organic content does not exceed 3%.
- Following ASTM D1544, AASHTO T21
- Validated through laboratory study
… BUT, color > 3 does NOT necessarily mean the organic content is >3% (i.e. black supernatant liquid could still be organic free)
Organics
Marls
Combined


II. Colorimetric Test
PURDUE
Soil 2 – 0 hr
Soil 2 – 2 hrs
Soil 2 – 4 hrs
Soil 2 – 8 hrs
Soil 2 – 12 hrs
Soil 2 – 24 hrs
Organics
Marls
Combined

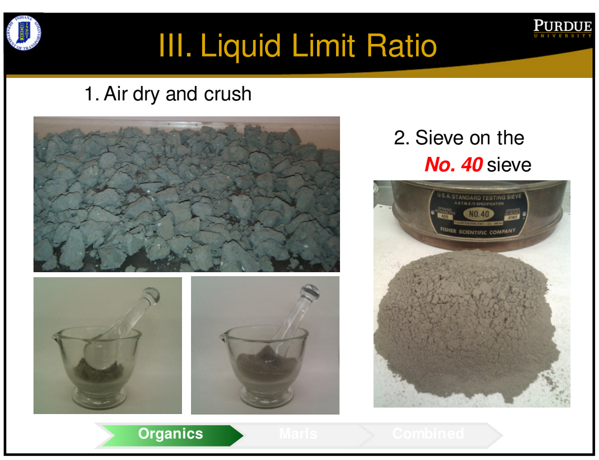
APPENDIX 1

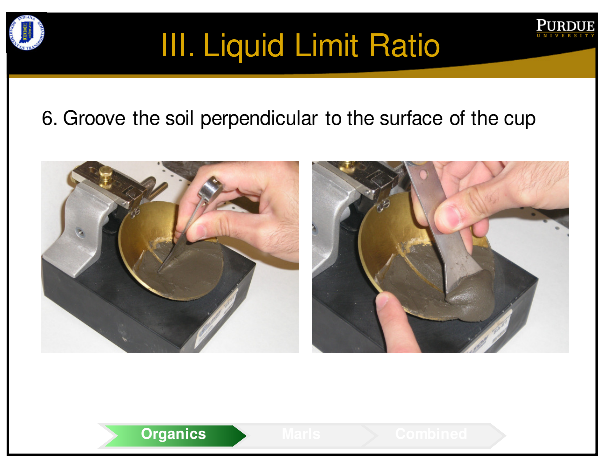

PURDUE
III. Liquid Limit Ratio
In brief….
Determine the decrease in liquid limit (LL) after oven drying soil
Standards:
(ASTM D4318 – 10, AASHTO T89 – 10)
Organics
Marls
Combined


PURDUE
III. Liquid Limit Ratio
3. Mix with distilled water to obtain a soil paste
4. Place in a humid room* for 24 hrs to temper
*Or any other controlled environment
Organics
Marls
Combined


PURDUE
III. Liquid Limit Ratio
Premise
▪ Oven drying at 110 °C affects the ability of organic matter to "hold on" to water, reducing the LL
Concern
▪ Test repeatability also affects LL_{ratio} (especially if different operators and laboratories)
Organics
Marls
Combined


PURDUE
III. Liquid Limit Ratio
5. Place soil in the Casagrande cup to a maximum depth of ½ inch
Organics
Marls
Combined

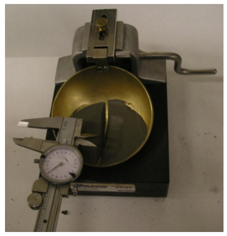

PURDUE
III. Liquid Limit Ratio
1. Air dry and crush
2. Sieve on the No. 40 sieve
Organics
Marls
Combined


PURDUE
III. Liquid Limit Ratio
6. Groove the soil perpendicular to the surface of the cup
Organics
Marls
Combined

APPENDIX 1

III. Liquid Limit Ratio

7. Turn the crank at a rate of 2 blows/sec until the groove closes for a length of ½ inch (13 mm)



Organics Marls Combined

III. Liquid Limit Ratio

Important Notes

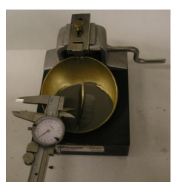
- Repeatability of test can affect results → both limits should be performed:
  - *a) In same laboratory*
  - *b) With same Casagrande cup*
  - *c) By same Operator*
- **None of these three tests can work ALONE. Effective in COMBINATION!**

Organics Marls Combined

III. Liquid Limit Ratio

8. Oven-dry another sample at 110℃ for 24 hours*

9. Repeat determination of Liquid Limit

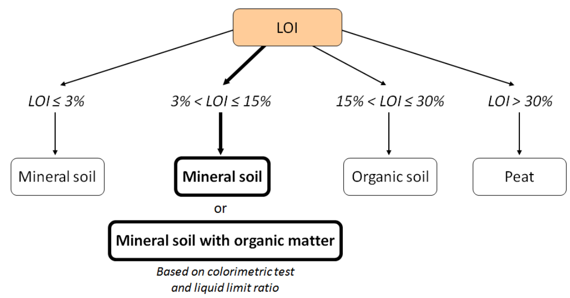


* Until no loss in mass is observed

Organics Marls Combined

CLASSIFICATION OF ORGANICS

Figure O1



Organics Marls Combined

III. Liquid Limit Ratio

- **Calculation of Liquid Limit ratio**

$$LL_{ratio} = \frac{LL_{\text{oven dried}}}{LL_{\text{not dried}}}$$

- **Criterion**

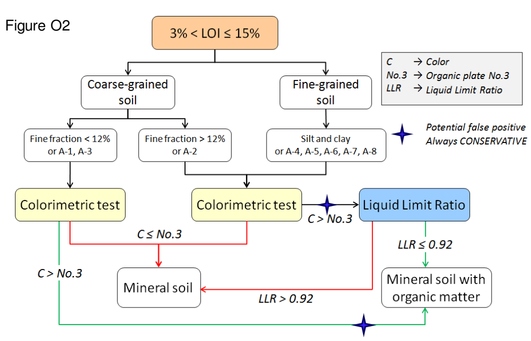
Only need to perform LL_{ratio} for soils with color >3 in colorimetric test

If $LL_{ratio} > 0.92$ ➡ Organic content is < 3%

Organics Marls Combined

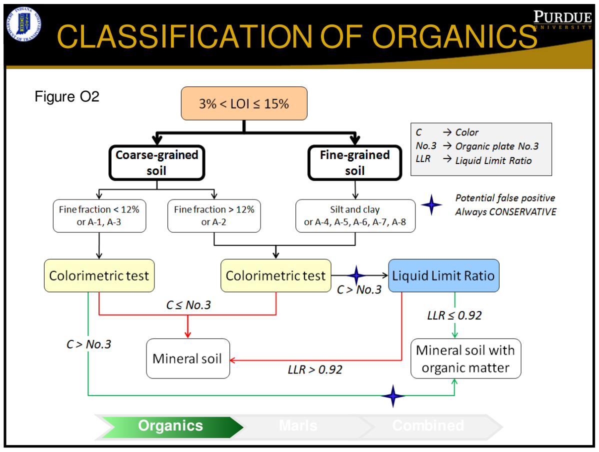
CLASSIFICATION OF ORGANICS

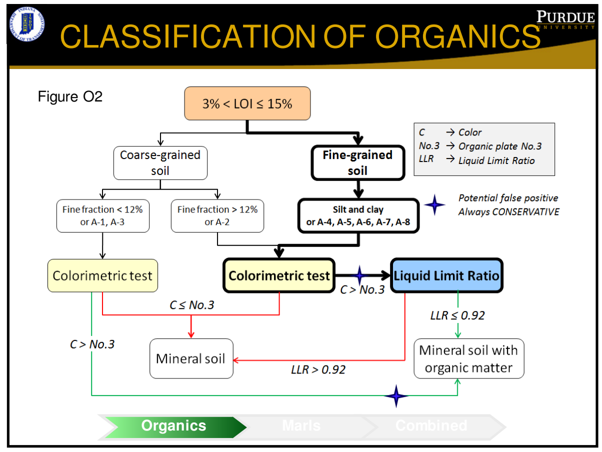
Figure O2



Organics Marls Combined

APPENDIX 1


CLASSIFICATION OF ORGANICS
PURDUE UNIVERSITY
Figure O2
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
Mineral soil with organic matter
LLR > 0.92
Organics
Marls
Combined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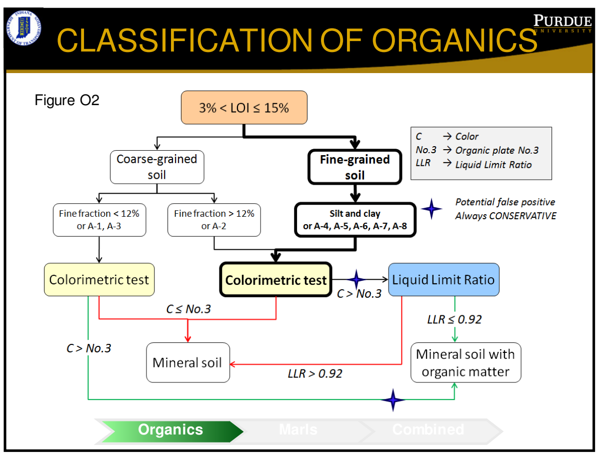
Marls
Combined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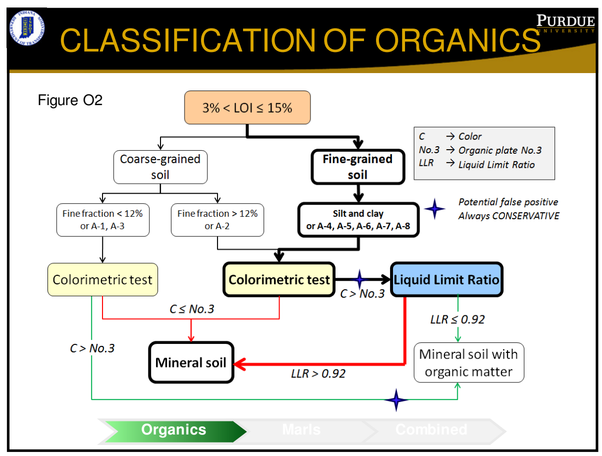
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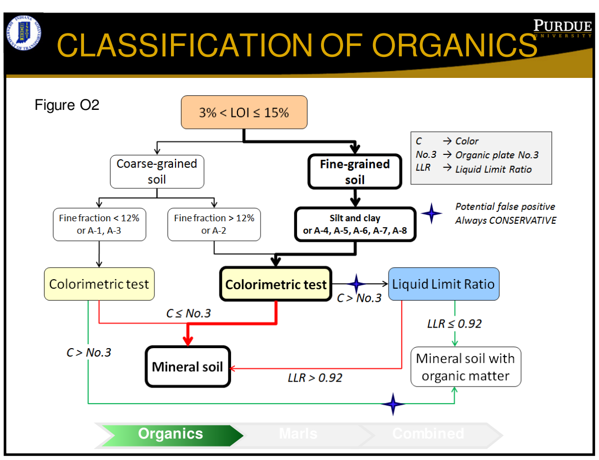
LLR > 0.92
Organics
Marls
Combined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Mineral soil with organic matter
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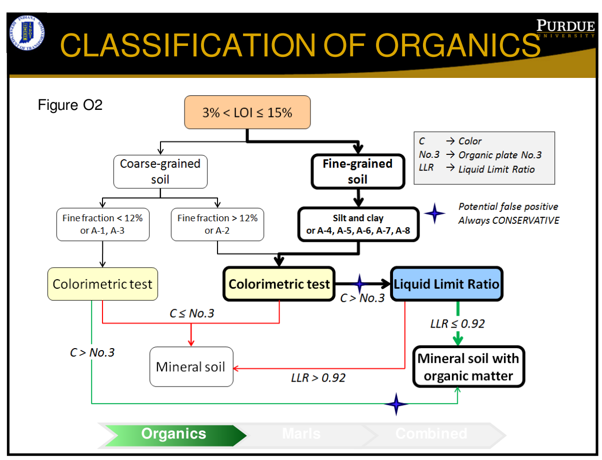
Organics
Marls
Combined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Mineral soil with organic matter
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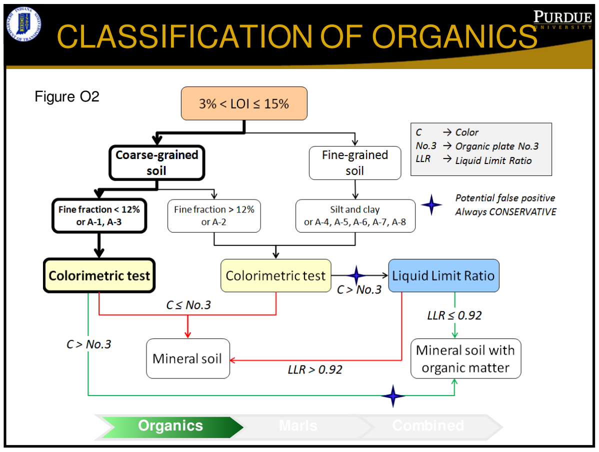
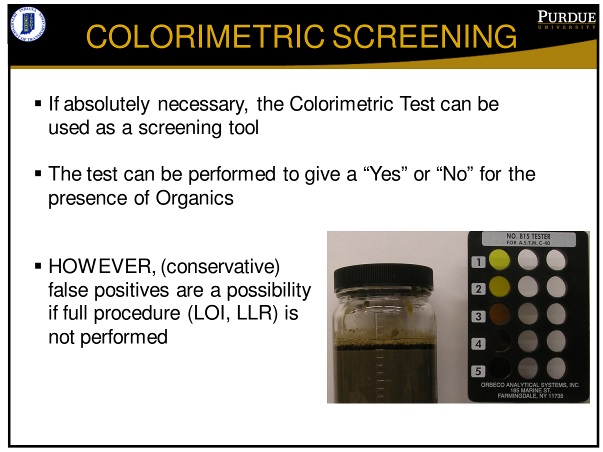
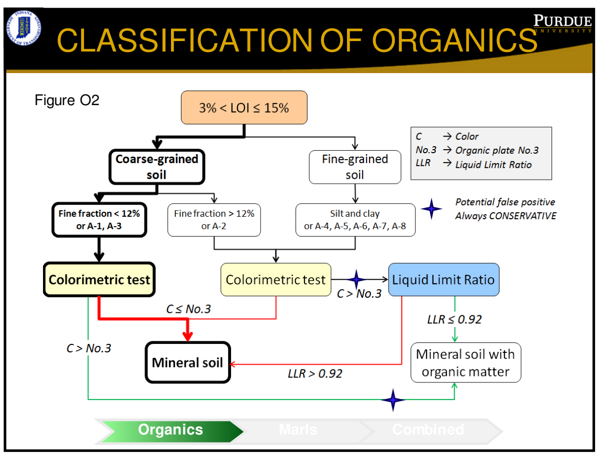
Organics
Marls
Combined

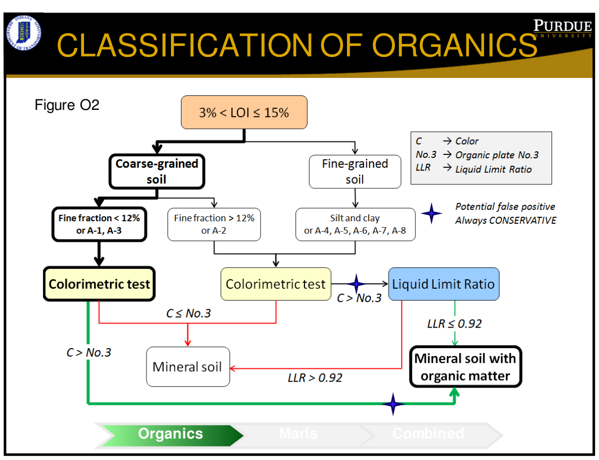
APPENDIX 1

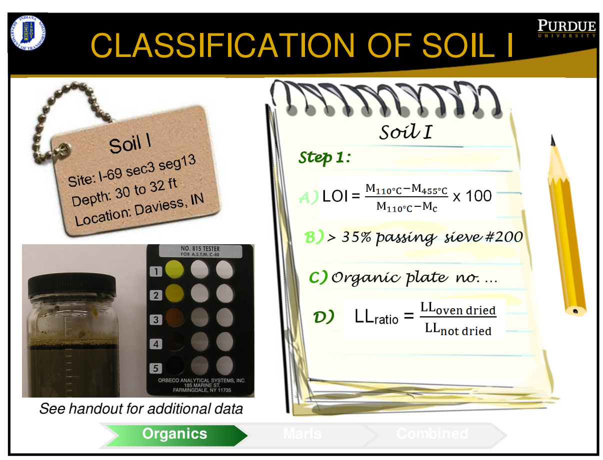

CLASSIFICATION OF ORGANICS
PURDUE
Figure O2
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter
Organics
Marls
Combined


COLORIMETRIC SCREENING
PURDUE
If absolutely necessary, the Colorimetric Test can be used as a screening tool
The test can be performed to give a "Yes" or "No" for the presence of Organics
HOWEVER, (conservative) false positives are a possibility if full procedure (LOI, LLR) is not performed
NO. 815 TESTER FOR A.S.T.M. C-40
1
2
3
4
5

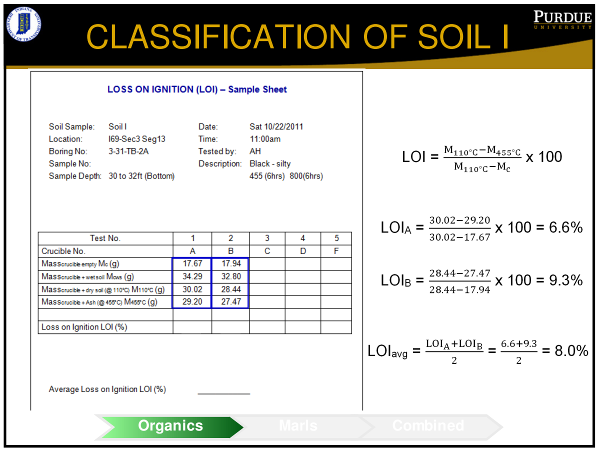

CLASSIFICATION OF ORGANICS
PURDUE
Figure O2
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter
Organics
Marls
Combined

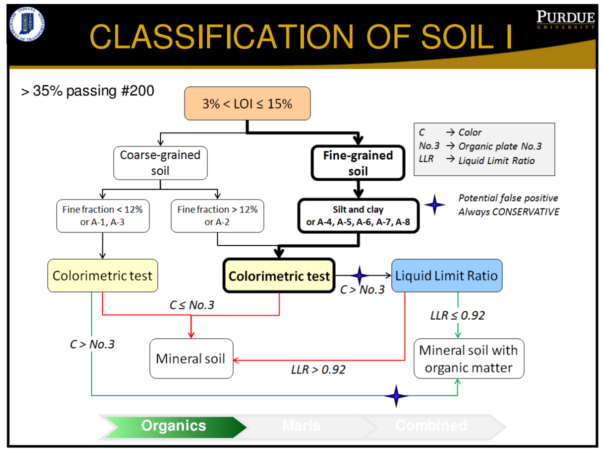

PURDUE
PRACTICE TIME
Refer to 'Classification examples.pdf' and 'Classification charts.pdf'
Organics
Marls
Combined

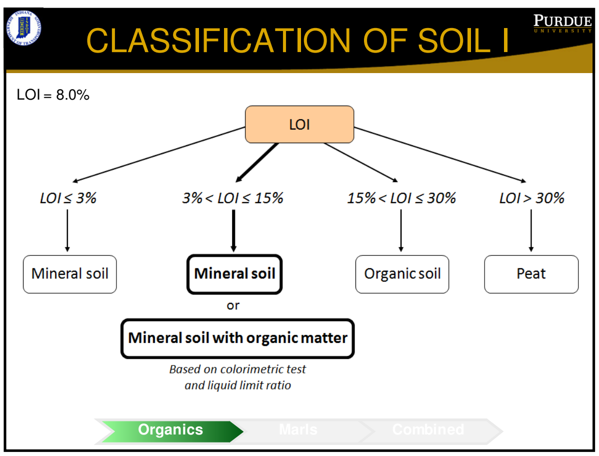

CLASSIFICATION OF ORGANICS
PURDUE
Figure O2
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter
Organics
Marls
Combined

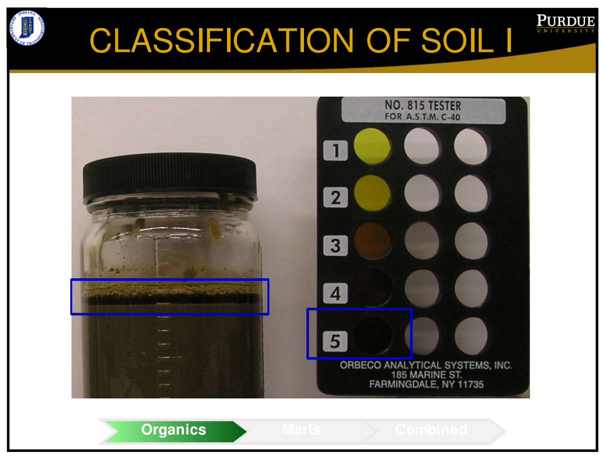

CLASSIFICATION OF SOIL I
PURDUE
Soil I
Site: I-69 sec3 seg13
Depth: 30 to 32 ft
Location: Daviess, IN
Soil I
Step 1:
A) LOI = $\frac{M_{110°C}-M_{455°C}}{M_{110°C}-M_c}$ x 100
B) > 35% passing sieve #200
C) Organic plate no. ...
D) $LL_{ratio} = \frac{LL_{oven\ dried}}{LL_{not\ dried}}$
See handout for additional data
Organics
Marls
Combined

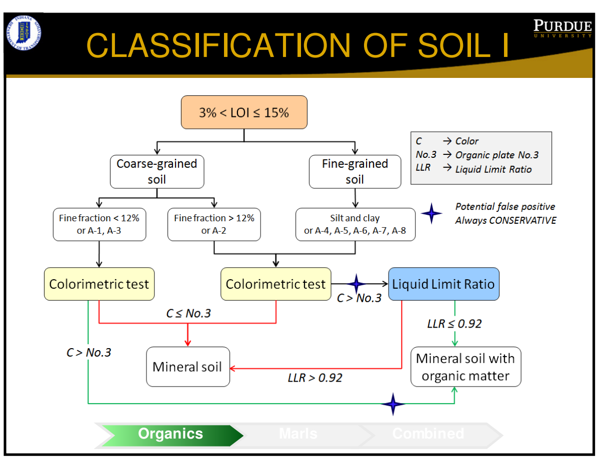
APPENDIX 1

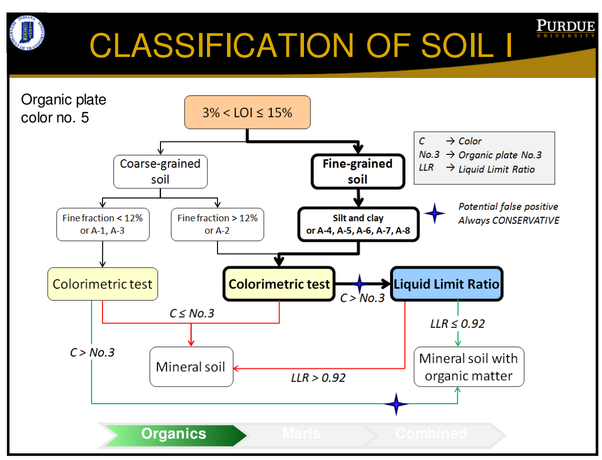

CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
LOSS ON IGNITION (LOI) – Sample Sheet
Soil Sample: Soil I
Location: I69-Sec3 Seg13
Boring No: 3-31-TB-2A
Sample No:
Sample Depth: 30 to 32ft (Bottom)
Date: Sat 10/22/2011
Time: 11:00am
Tested by: AH
Description: Black - silty
455 (6hrs) 800(6hrs)
Test No. | 1 | 2 | 3 | 4 | 5
Crucible No. | A | B | C | D | F
Mass crucible empty Mc (g) | 17.67 | 17.94
Mass crucible + wet soil Mcws (g) | 34.29 | 32.80
Mass crucible + dry soil (@ 110°C) M110°C (g) | 30.02 | 28.44
Mass crucible + Ash (@ 455°C) M455°C (g) | 29.20 | 27.47
Loss on Ignition LOI (%)
Average Loss on Ignition LOI (%)
LOI = (M110°C − M455°C) / (M110°C − Mc) x 100
LOIA = (30.02−29.20) / (30.02−17.67) x 100 = 6.6%
LOIB = (28.44−27.47) / (28.44−17.94) x 100 = 9.3%
LOIavg = (LOIA+LOIB) / 2 = (6.6+9.3) / 2 = 8.0%
Organics
Marls
Combined


CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
> 35% passing #200
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter
Organics
Marls
Combined

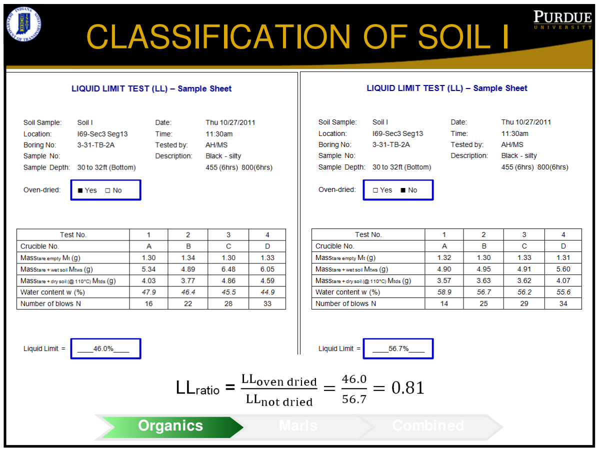

CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
LOI = 8.0%
LOI
LOI ≤ 3%
3% < LOI ≤ 15%
15% < LOI ≤ 30%
LOI > 30%
Mineral soil
Mineral soil
Organic soil
Peat
or
Mineral soil with organic matter
Based on colorimetric test and liquid limit ratio
Organics
Marls
Combined


CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
NO. 815 TESTER FOR A.S.T.M. C-40
1
2
3
4
5
ORBECO ANALYTICAL SYSTEMS, INC.
185 MARINE ST.
FARMINGDALE, NY 11735
Organics
Marls
Combined

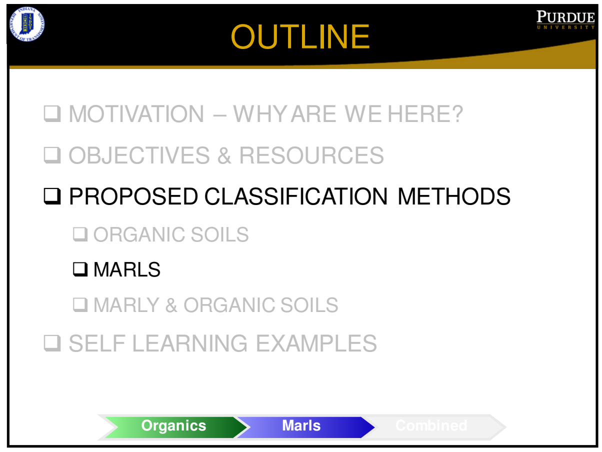

CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter
Organics
Marls
Combined


CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
Organic plate color no. 5
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter
Organics
Marls
Combined

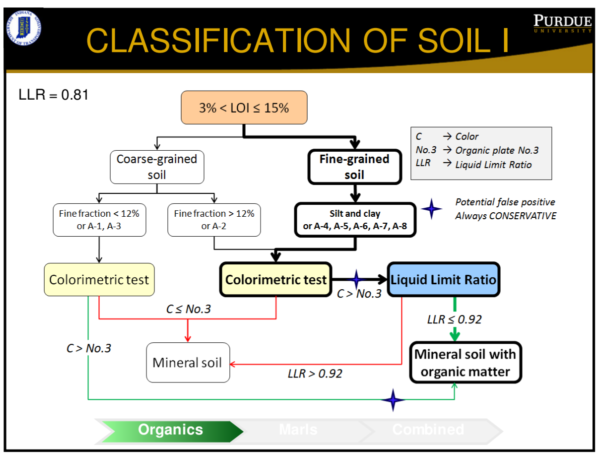
APPENDIX 1



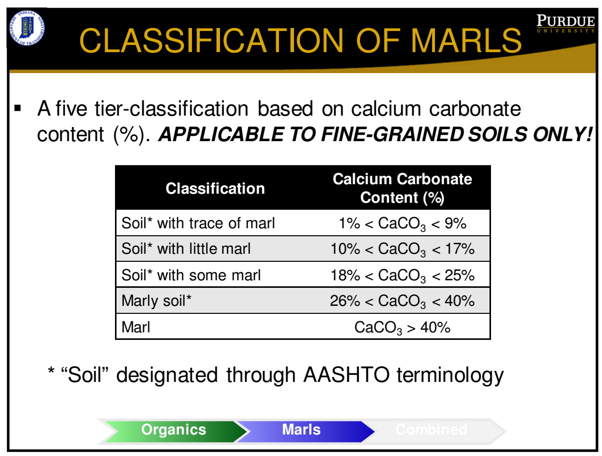
CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
LIQUID LIMIT TEST (LL) – Sample Sheet
Soil Sample: Soil I
Location: I69-Sec3 Seg13
Boring No: 3-31-TB-2A
Sample No:
Sample Depth: 30 to 32ft (Bottom)
Date: Thu 10/27/2011
Time: 11:30am
Tested by: AH/MS
Description: Black - silty
455 (6hrs) 800(6hrs)
Oven-dried: ■ Yes □ No
Test No. 1 2 3 4
Crucible No. A B C D
Mass tare empty Mt (g) 1.30 1.34 1.30 1.33
Mass tare + wet soil Mtws (g) 5.34 4.89 6.48 6.05
Mass tare + dry soil (@ 110°C) Mtds (g) 4.03 3.77 4.86 4.59
Water content w (%) 47.9 46.4 45.5 44.9
Number of blows N 16 22 28 33
Liquid Limit = 46.0%
LIQUID LIMIT TEST (LL) – Sample Sheet
Soil Sample: Soil I
Location: I69-Sec3 Seg13
Boring No: 3-31-TB-2A
Sample No:
Sample Depth: 30 to 32ft (Bottom)
Date: Thu 10/27/2011
Time: 11:30am
Tested by: AH/MS
Description: Black - silty
455 (6hrs) 800(6hrs)
Oven-dried: □ Yes ■ No
Test No. 1 2 3 4
Crucible No. A B C D
Mass tare empty Mt (g) 1.32 1.30 1.33 1.31
Mass tare + wet soil Mtws (g) 4.90 4.95 4.91 5.60
Mass tare + dry soil (@ 110°C) Mtds (g) 3.57 3.63 3.62 4.07
Water content w (%) 58.9 56.7 56.2 55.6
Number of blows N 14 25 29 34
Liquid Limit = 56.7%
$LL_{ratio} = \frac{LL_{oven\ dried}}{LL_{not\ dried}} = \frac{46.0}{56.7} = 0.81$
Organics Marls Combined



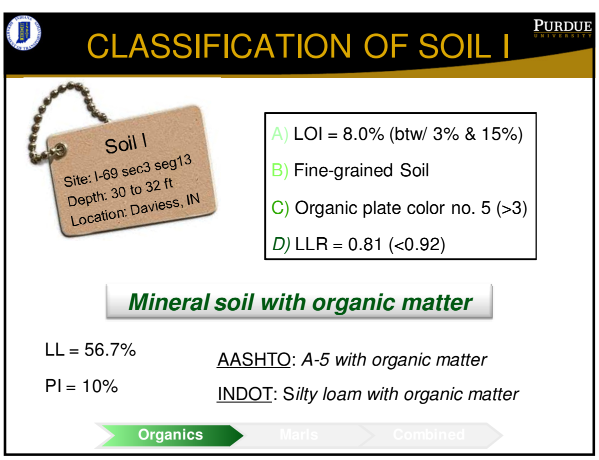
OUTLINE
PURDUE UNIVERSITY
❑ MOTIVATION – WHY ARE WE HERE?
❑ OBJECTIVES & RESOURCES
❑ PROPOSED CLASSIFICATION METHODS
❑ ORGANIC SOILS
❑ MARLS
❑ MARLY & ORGANIC SOILS
❑ SELF LEARNING EXAMPLES
Organics Marls Combined



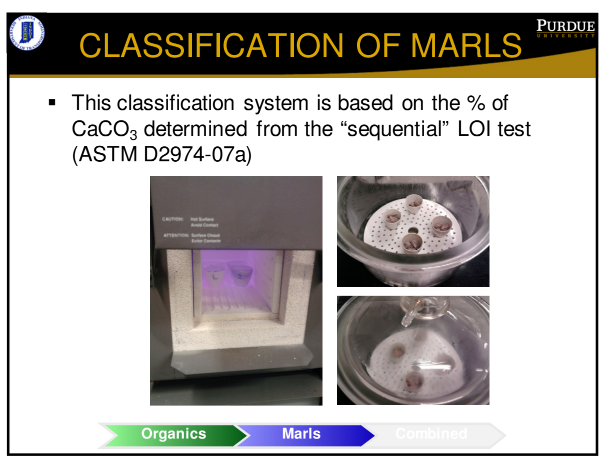
CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
LLR = 0.81
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
Mineral soil with organic matter
LLR > 0.92
Organics Marls Combined



CLASSIFICATION OF MARLS
PURDUE UNIVERSITY
▪ A five tier-classification based on calcium carbonate content (%). APPLICABLE TO FINE-GRAINED SOILS ONLY!
Classification | Calcium Carbonate Content (%)
Soil* with trace of marl | 1% < $CaCO_3$ < 9%
Soil* with little marl | 10% < $CaCO_3$ < 17%
Soil* with some marl | 18% < $CaCO_3$ < 25%
Marly soil* | 26% < $CaCO_3$ < 40%
Marl | $CaCO_3$ > 40%
* "Soil" designated through AASHTO terminology
Organics Marls Combined

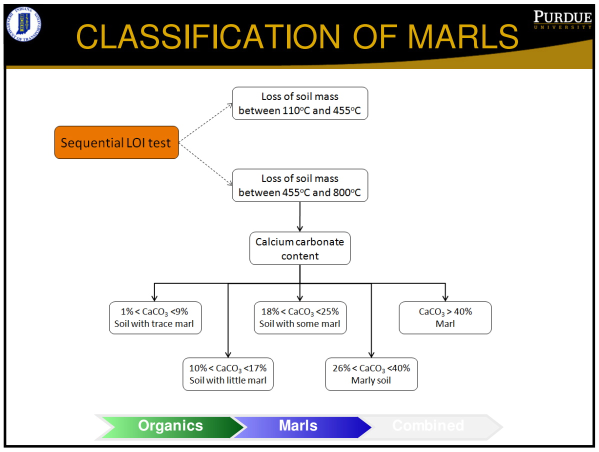


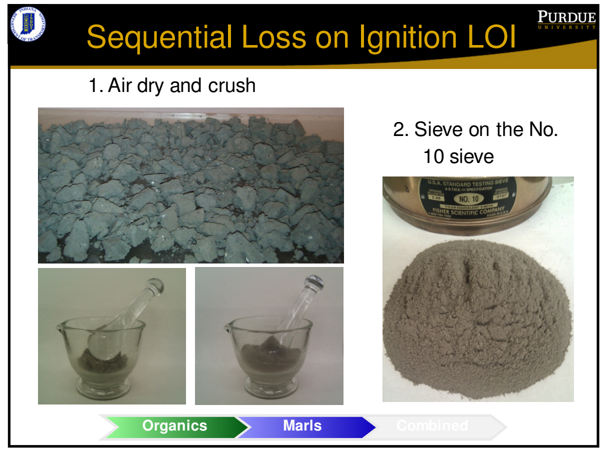
CLASSIFICATION OF SOIL I
PURDUE UNIVERSITY
Soil I
Site: I-69 sec3 seg13
Depth: 30 to 32 ft
Location: Davies, IN
A) LOI = 8.0% (btw/ 3% & 15%)
B) Fine-grained Soil
C) Organic plate color no. 5 (>3)
D) LLR = 0.81 (<0.92)
Mineral soil with organic matter
LL = 56.7%
PI = 10%
AASHTO: A-5 with organic matter
INDOT: Silty loam with organic matter
Organics Marls Combined

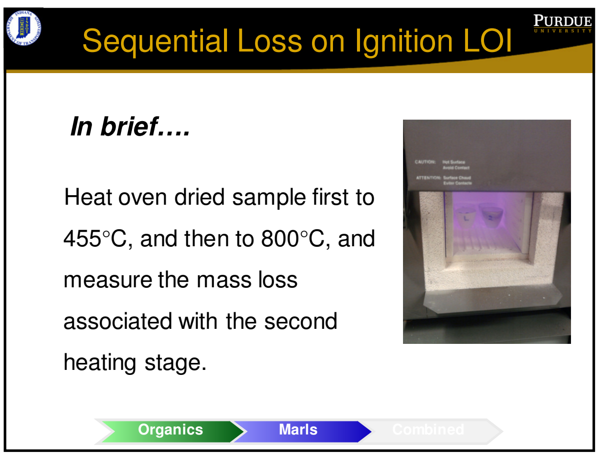


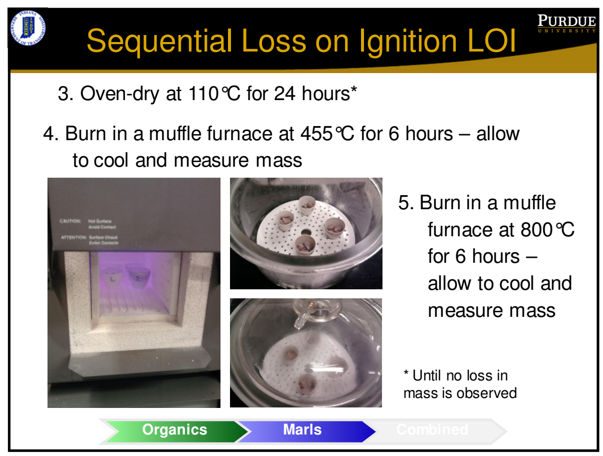
CLASSIFICATION OF MARLS
PURDUE UNIVERSITY
▪ This classification system is based on the % of $CaCO_3$ determined from the "sequential" LOI test (ASTM D2974-07a)
Organics Marls

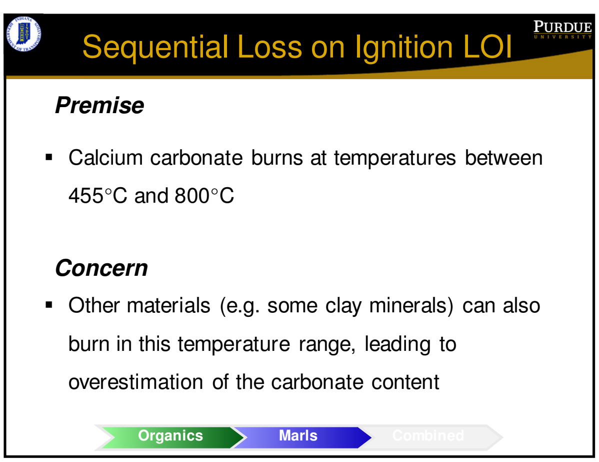
APPENDIX 1

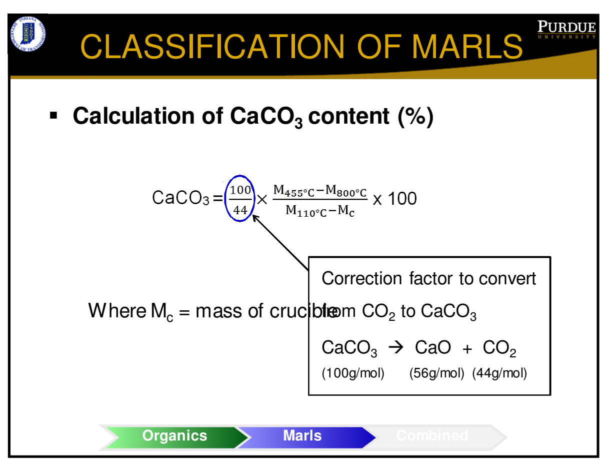

CLASSIFICATION OF MARLS
PURDUE UNIVERSITY
Sequential LOI test
Loss of soil mass between 110°C and 455°C
Loss of soil mass between 455°C and 800°C
Calcium carbonate content
1% < $CaCO_3$ <9% Soil with trace marl
18% < $CaCO_3$ <25% Soil with some marl
$CaCO_3$ > 40% Marl
10% < $CaCO_3$ <17% Soil with little marl
26% < $CaCO_3$ <40% Marly soil
Organics
Marls
Combined


Sequential Loss on Ignition LOI
PURDUE UNIVERSITY
1. Air dry and crush
2. Sieve on the No. 10 sieve
Organics
Marls
Combined

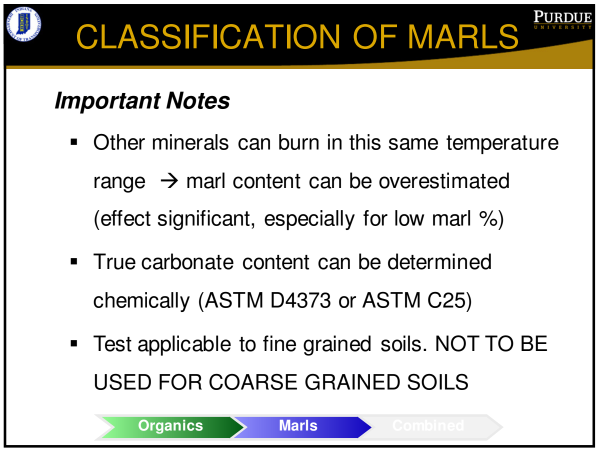

Sequential Loss on Ignition LOI
PURDUE UNIVERSITY
In brief….
Heat oven dried sample first to 455°C, and then to 800°C, and measure the mass loss associated with the second heating stage.
Organics
Marls
Combined

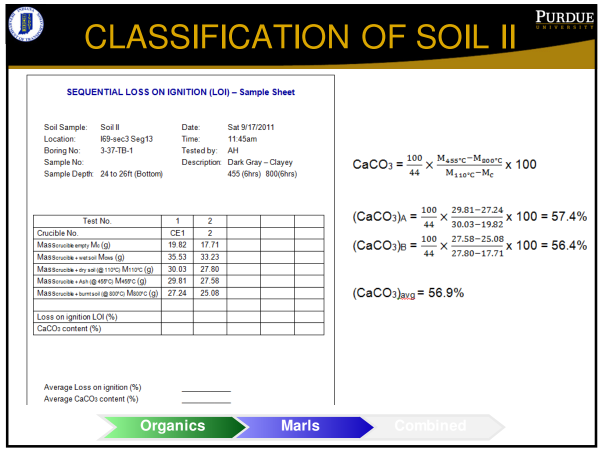

Sequential Loss on Ignition LOI
PURDUE UNIVERSITY
3. Oven-dry at 110°C for 24 hours*
4. Burn in a muffle furnace at 455°C for 6 hours – allow to cool and measure mass
5. Burn in a muffle furnace at 800°C for 6 hours – allow to cool and measure mass
* Until no loss in mass is observed
Organics
Marls
Combined


Sequential Loss on Ignition LOI
PURDUE UNIVERSITY
Premise
▪ Calcium carbonate burns at temperatures between 455°C and 800°C
Concern
▪ Other materials (e.g. some clay minerals) can also burn in this temperature range, leading to overestimation of the carbonate content
Organics
Marls
Combined


CLASSIFICATION OF MARLS
PURDUE UNIVERSITY
▪ Calculation of $CaCO_3$ content (%)
$CaCO_3 = \frac{100}{44} \times \frac{M_{455°C} - M_{800°C}}{M_{110°C} - M_c} \times 100$
Where M_c = mass of crucible
Correction factor to convert from CO_2 to $CaCO_3$
$CaCO_3 \rightarrow CaO + CO_2$
(100g/mol) (56g/mol) (44g/mol)
Organics
Marls
Combined

APPENDIX 1





Test No.	1	2			
Crucible No.	CE1	2			
$Mass_{crucible\ empty}$ M_C (g)	19.82	17.71			
$Mass_{crucible + wet\ soil}$ M_{CWS} (g)	35.53	33.23			
$Mass_{crucible + dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	30.03	27.80			
$Mass_{crucible + Ash\ (@\ 455°C)}$ $M_{455°C}$ (g)	29.81	27.58			
$Mass_{crucible + burnt\ soil\ (@\ 800°C)}$ $M_{800°C}$ (g)	27.24	25.08			
Loss on ignition LOI (%)					
$CaCO_3$ content (%)					

Average Loss on ignition (%) ________

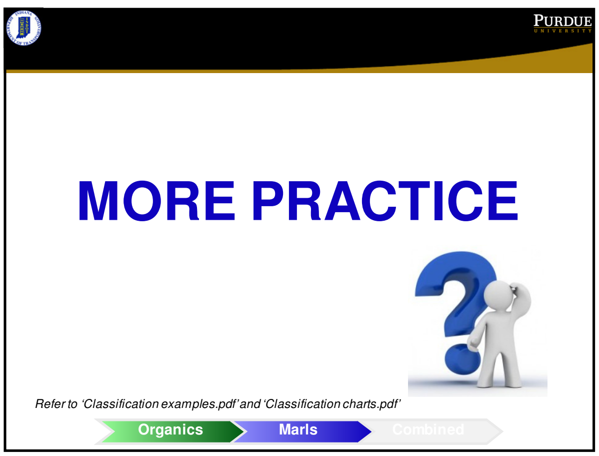
Average $CaCO_3$ content (%) ________

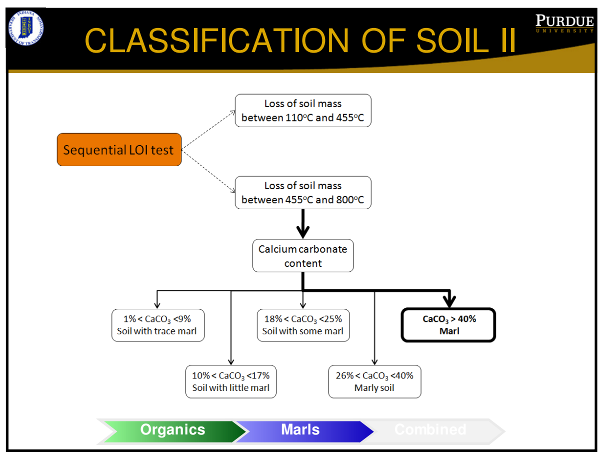
$$CaCO_3 = \frac{100}{44} \times \frac{M_{455°C} - M_{800°C}}{M_{110°C} - M_C} \times 100$$

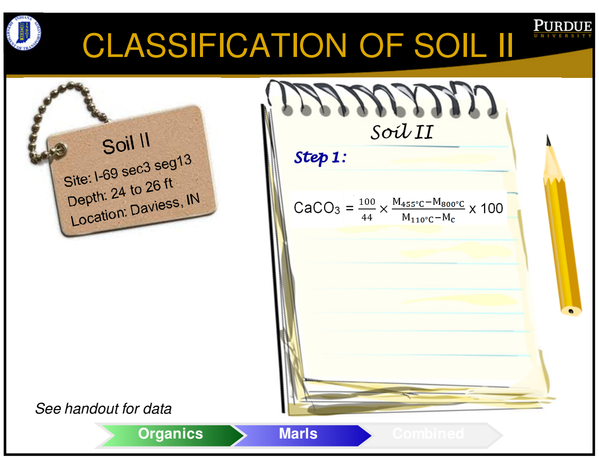
$$(CaCO_3)_A = \frac{100}{44} \times \frac{29.81 - 27.24}{30.03 - 19.82} \times 100 = 57.4\%$$

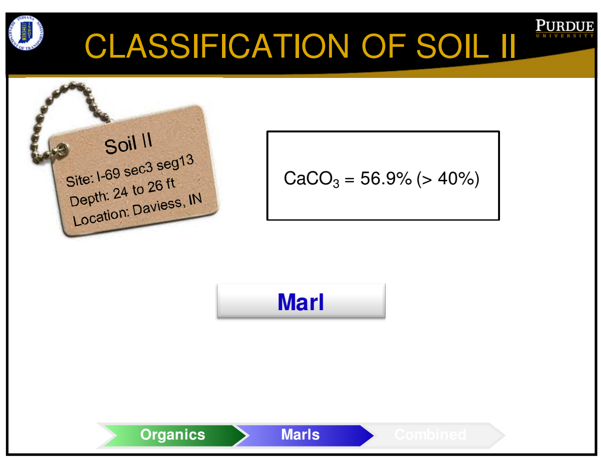
$$(CaCO_3)_B = \frac{100}{44} \times \frac{27.58 - 25.08}{27.80 - 17.71} \times 100 = 56.4\%$$

$$(CaCO_3)_{avg} = 56.9\%$$

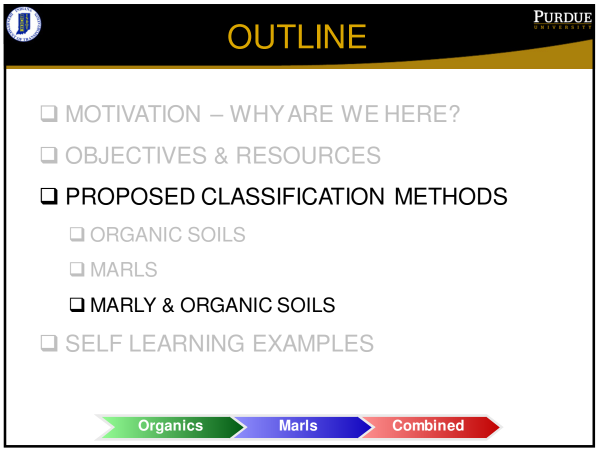


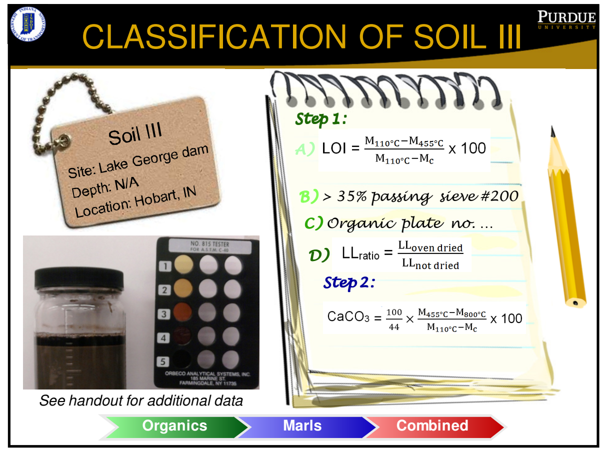


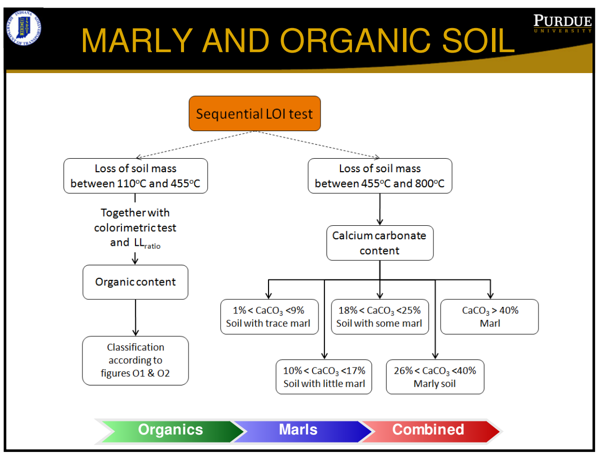


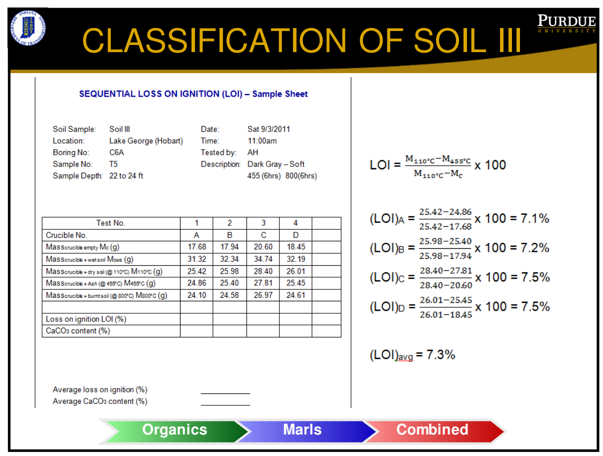


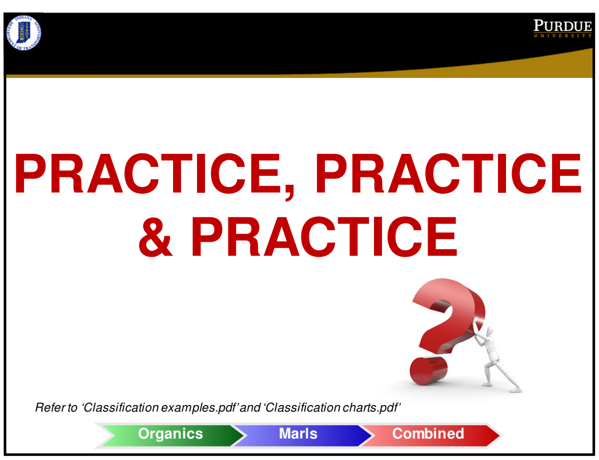
APPENDIX 1

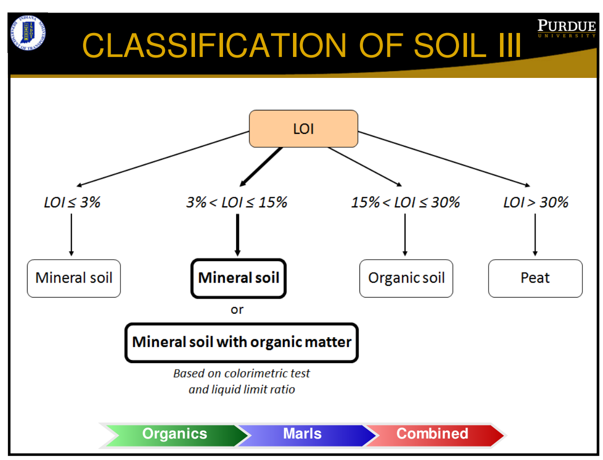

OUTLINE
PURDUE UNIVERSITY
MOTIVATION – WHY ARE WE HERE?
OBJECTIVES & RESOURCES
PROPOSED CLASSIFICATION METHODS
ORGANIC SOILS
MARLS
MARLY & ORGANIC SOILS
SELF LEARNING EXAMPLES
Organics
Marls
Combined


CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
Soil III
Site: Lake George dam
Depth: N/A
Location: Hobart, IN
Step 1:
A) LOI = $\frac{M_{110°C}-M_{455°C}}{M_{110°C}-M_C}$ x 100
B) > 35% passing sieve #200
C) Organic plate no. ...
D) $LL_{ratio} = \frac{LL_{oven\ dried}}{LL_{not\ dried}}$
Step 2:
$CaCO_3 = \frac{100}{44} \times \frac{M_{455°C}-M_{800°C}}{M_{110°C}-M_C}$ x 100
See handout for additional data
Organics
Marls
Combined

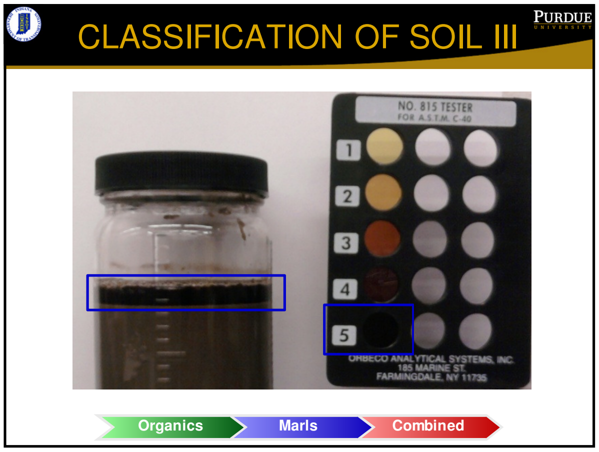

MARLY AND ORGANIC SOIL
PURDUE UNIVERSITY
Sequential LOI test
Loss of soil mass between 110°C and 455°C
Loss of soil mass between 455°C and 800°C
Together with colorimetric test and LL_{ratio}
Organic content
Classification according to figures O1 & O2
Calcium carbonate content
1% < $CaCO_3$ <9% Soil with trace marl
18% < $CaCO_3$ <25% Soil with some marl
$CaCO_3$ > 40% Marl
10% < $CaCO_3$ <17% Soil with little marl
26% < $CaCO_3$ <40% Marly soil
Organics
Marls
Combined


CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
SEQUENTIAL LOSS ON IGNITION (LOI) – Sample Sheet
Soil Sample: Soil III
Location: Lake George (Hobart)
Boring No: C6A
Sample No: T5
Sample Depth: 22 to 24 ft
Date: Sat 9/3/2011
Time: 11:00am
Tested by: AH
Description: Dark Gray – Soft
455 (6hrs) 800(6hrs)
Test No. | 1 | 2 | 3 | 4
Crucible No. | A | B | C | D
$Mass_{crucible\ empty}$ M_C (g) | 17.68 | 17.94 | 20.60 | 18.45
$Mass_{crucible + wet\ soil}$ M_{CWS} (g) | 31.32 | 32.34 | 34.74 | 32.19
$Mass_{crucible + dry\ soil\ (@ 110°C)}$ $M_{110°C}$ (g) | 25.42 | 25.98 | 28.40 | 26.01
$Mass_{crucible + Ash\ (@ 455°C)}$ $M_{455°C}$ (g) | 24.86 | 25.40 | 27.81 | 25.45
$Mass_{crucible + burnt\ soil\ (@ 800°C)}$ $M_{800°C}$ (g) | 24.10 | 24.58 | 26.97 | 24.61
Loss on ignition LOI (%)
$CaCO_3$ content (%)
Average loss on ignition (%)
Average $CaCO_3$ content (%)
LOI = $\frac{M_{110°C}-M_{455°C}}{M_{110°C}-M_C}$ x 100
$(LOI)_A = \frac{25.42-24.86}{25.42-17.68}$ x 100 = 7.1%
$(LOI)_B = \frac{25.98-25.40}{25.98-17.94}$ x 100 = 7.2%
$(LOI)_C = \frac{28.40-27.81}{28.40-20.60}$ x 100 = 7.5%
$(LOI)_D = \frac{26.01-25.45}{26.01-18.45}$ x 100 = 7.5%
$(LOI)_{avg}$ = 7.3%
Organics
Marls
Combined

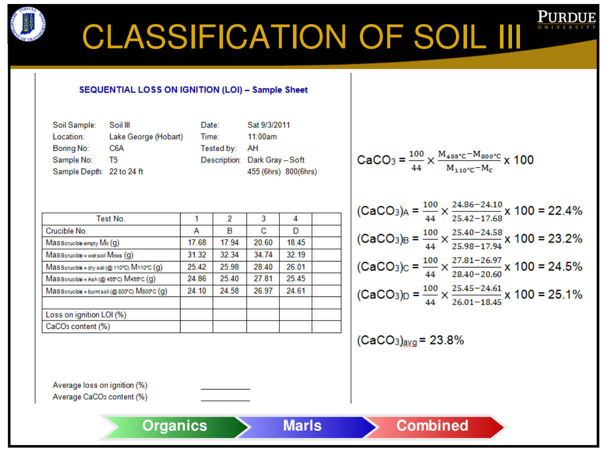

PURDUE UNIVERSITY
PRACTICE, PRACTICE & PRACTICE
Refer to 'Classification examples.pdf' and 'Classification charts.pdf'
Organics
Marls
Combined


CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
LOI
LOI ≤ 3%
3% < LOI ≤ 15%
15% < LOI ≤ 30%
LOI > 30%
Mineral soil
Mineral soil
Organic soil
Peat
or
Mineral soil with organic matter
Based on colorimetric test and liquid limit ratio
Organics
Marls
Combined

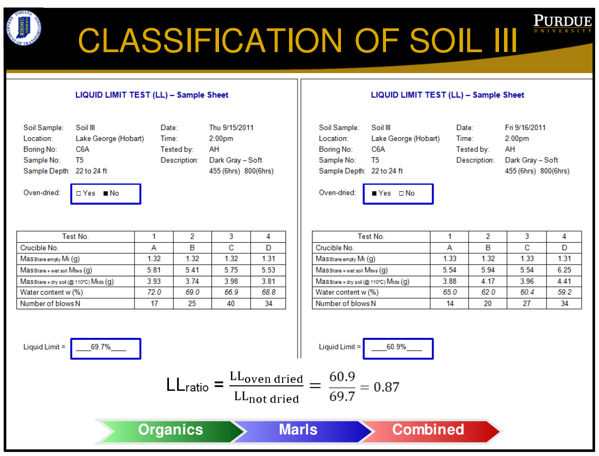
APPENDIX 1



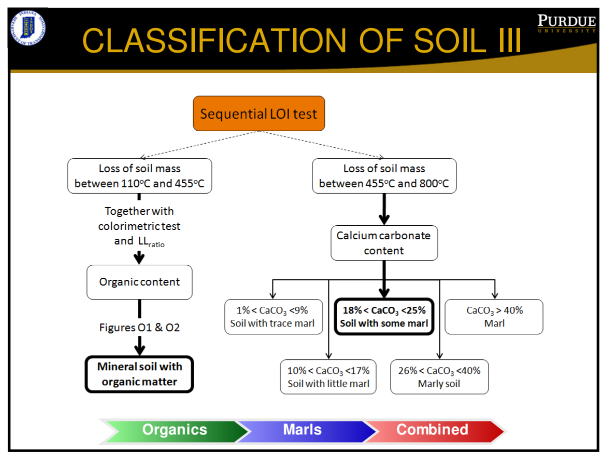
CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
NO. 815 TESTER FOR A.S.T.M. C-40
1
2
3
4
5
ORBECO ANALYTICAL SYSTEMS, INC.
185 MARINE ST.
FARMINGDALE, NY 11735
Organics
Marls
Combined



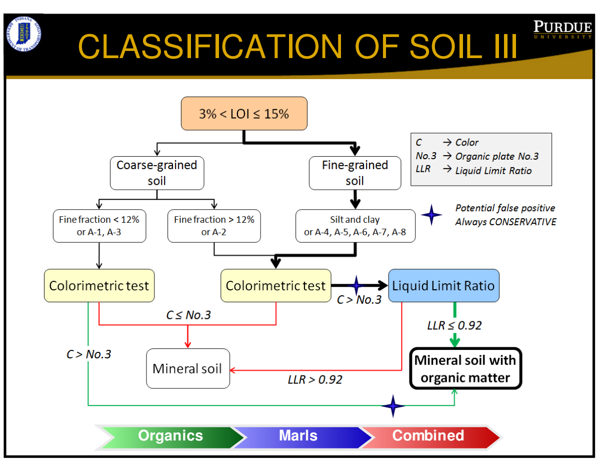
CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
SEQUENTIAL LOSS ON IGNITION (LOI) – Sample Sheet
Soil Sample: Soil III
Location: Lake George (Hobart)
Boring No: C6A
Sample No: T5
Sample Depth: 22 to 24 ft
Date: Sat 9/3/2011
Time: 11:00am
Tested by: AH
Description: Dark Gray – Soft
455 (6hrs) 800(6hrs)
Test No. 1 2 3 4
Crucible No. A B C D
Mass crucible empty Mc (g) 17.68 17.94 20.60 18.45
Mass crucible + wet soil Mcws (g) 31.32 32.34 34.74 32.19
Mass crucible + dry soil (@ 110°C) M110°C (g) 25.42 25.98 28.40 26.01
Mass crucible + Ash (@ 455°C) M455°C (g) 24.86 25.40 27.81 25.45
Mass crucible + burnt soil (@ 800°C) M800°C (g) 24.10 24.58 26.97 24.61
Loss on ignition LOI (%)
CaCO3 content (%)
Average loss on ignition (%)
Average CaCO3 content (%)
$CaCO_3 = \frac{100}{44} \times \frac{M_{455°C} - M_{800°C}}{M_{110°C} - M_c} \times 100$
$(CaCO_3)_A = \frac{100}{44} \times \frac{24.86 - 24.10}{25.42 - 17.68} \times 100 = 22.4\%$
$(CaCO_3)_B = \frac{100}{44} \times \frac{25.40 - 24.58}{25.98 - 17.94} \times 100 = 23.2\%$
$(CaCO_3)_C = \frac{100}{44} \times \frac{27.81 - 26.97}{28.40 - 20.60} \times 100 = 24.5\%$
$(CaCO_3)_D = \frac{100}{44} \times \frac{25.45 - 24.61}{26.01 - 18.45} \times 100 = 25.1\%$
$(CaCO_3)_{avg} = 23.8\%$
Organics
Marls
Combined



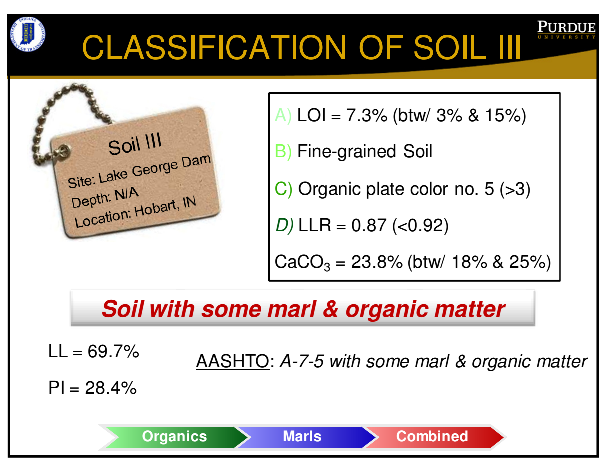
CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
LIQUID LIMIT TEST (LL) – Sample Sheet
Soil Sample: Soil III
Location: Lake George (Hobart)
Boring No: C6A
Sample No: T5
Sample Depth: 22 to 24 ft
Date: Thu 9/15/2011
Time: 2:00pm
Tested by: AH
Description: Dark Gray – Soft
455 (6hrs) 800(6hrs)
Oven-dried: □ Yes ■ No
Test No. 1 2 3 4
Crucible No. A B C D
Mass tare empty Mt (g) 1.32 1.32 1.32 1.31
Mass tare + wet soil Mtws (g) 5.81 5.41 5.75 5.53
Mass tare + dry soil (@ 110°C) Mtds (g) 3.93 3.74 3.98 3.81
Water content w (%) 72.0 69.0 66.9 68.8
Number of blows N 17 25 40 34
Liquid Limit = 69.7%
LIQUID LIMIT TEST (LL) – Sample Sheet
Soil Sample: Soil III
Location: Lake George (Hobart)
Boring No: C6A
Sample No: T5
Sample Depth: 22 to 24 ft
Date: Fri 9/16/2011
Time: 2:00pm
Tested by: AH
Description: Dark Gray – Soft
455 (6hrs) 800(6hrs)
Oven-dried: ■ Yes □ No
Test No. 1 2 3 4
Crucible No. A B C D
Mass tare empty Mt (g) 1.33 1.32 1.33 1.31
Mass tare + wet soil Mtws (g) 5.54 5.94 5.54 6.25
Mass tare + dry soil (@ 110°C) Mtds (g) 3.88 4.17 3.96 4.41
Water content w (%) 65.0 62.0 60.4 59.2
Number of blows N 14 20 27 34
Liquid Limit = 60.9%
$LL_{ratio} = \frac{LL_{oven\ dried}}{LL_{not\ dried}} = \frac{60.9}{69.7} = 0.87$
Organics
Marls
Combined



CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
Sequential LOI test
Loss of soil mass between 110°C and 455°C
Loss of soil mass between 455°C and 800°C
Together with colorimetric test and LL_{ratio}
Organic content
Figures O1 & O2
Mineral soil with organic matter
Calcium carbonate content
1% < $CaCO_3$ <9% Soil with trace marl
18% < $CaCO_3$ <25% Soil with some marl
$CaCO_3$ > 40% Marl
10% < $CaCO_3$ <17% Soil with little marl
26% < $CaCO_3$ <40% Marly soil
Organics
Marls
Combined

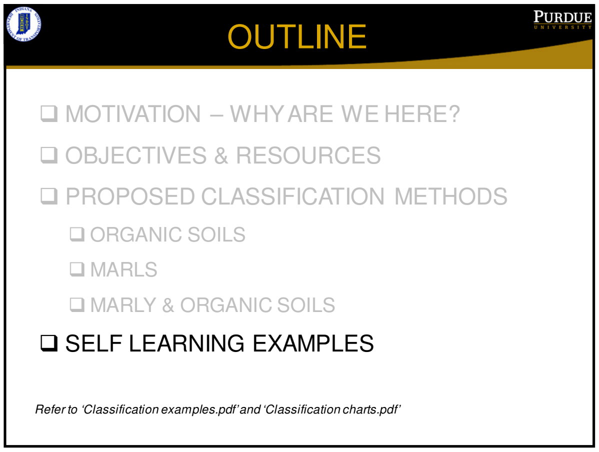


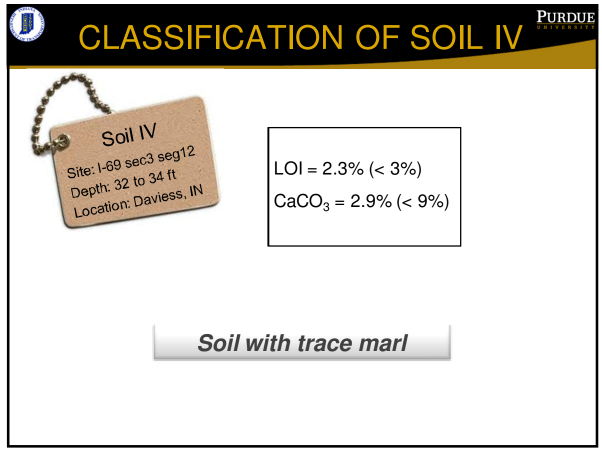
CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter
Organics
Marls
Combined

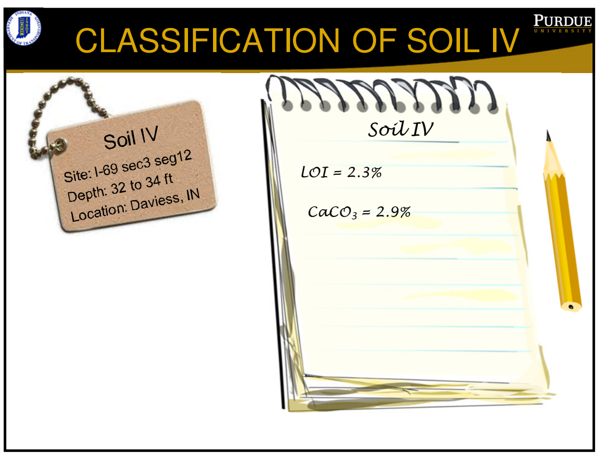


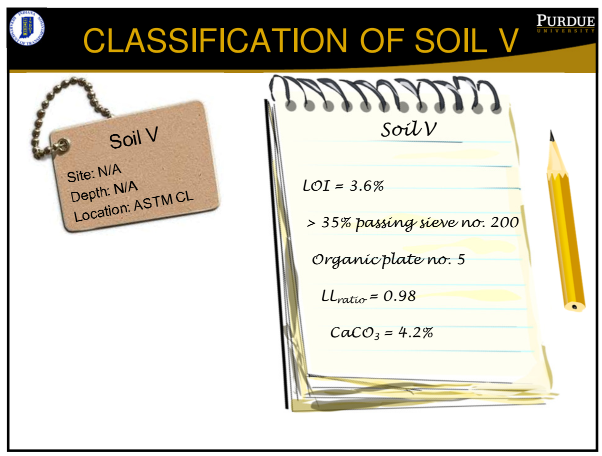
CLASSIFICATION OF SOIL III
PURDUE UNIVERSITY
Soil III
Site: Lake George Dam
Depth: N/A
Location: Hobart, IN
A) LOI = 7.3% (btw/ 3% & 15%)
B) Fine-grained Soil
C) Organic plate color no. 5 (>3)
D) LLR = 0.87 (<0.92)
$CaCO_3$ = 23.8% (btw/ 18% & 25%)
Soil with some marl & organic matter
LL = 69.7%
PI = 28.4%
AASHTO: A-7-5 with some marl & organic matter
Organics
Marls
Combined

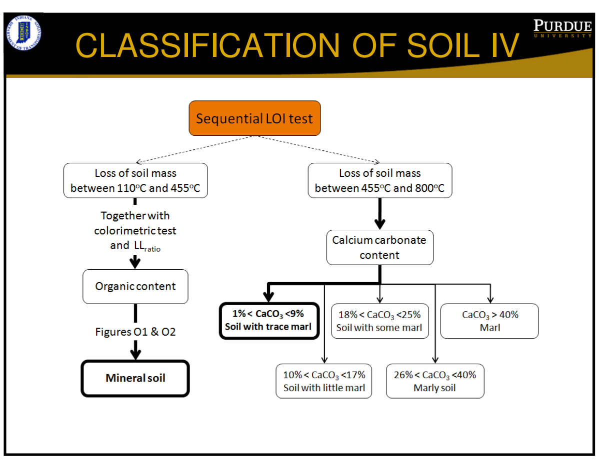
APPENDIX 1

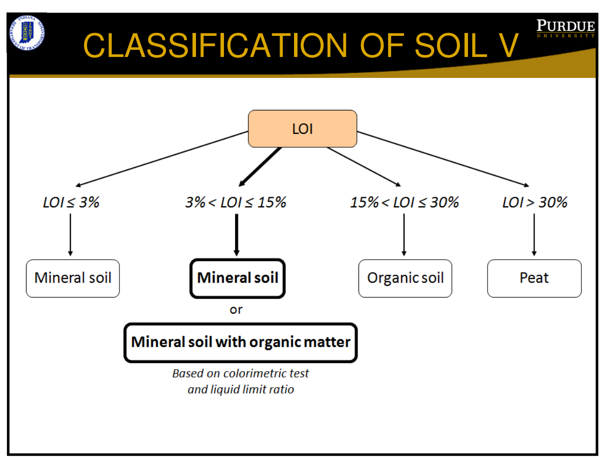

PURDUE
OUTLINE
MOTIVATION – WHY ARE WE HERE?
OBJECTIVES & RESOURCES
PROPOSED CLASSIFICATION METHODS
ORGANIC SOILS
MARLS
MARLY & ORGANIC SOILS
SELF LEARNING EXAMPLES
Refer to 'Classification examples.pdf' and 'Classification charts.pdf'


PURDUE
CLASSIFICATION OF SOIL IV
Soil IV
Site: I-69 sec3 seg12
Depth: 32 to 34 ft
Location: Daviess, IN
LOI = 2.3% (< 3%)
$CaCO_3$ = 2.9% (< 9%)
Soil with trace marl

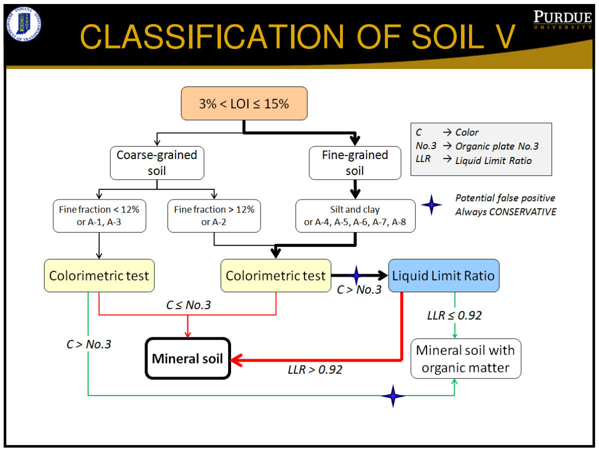

PURDUE
CLASSIFICATION OF SOIL IV
Soil IV
Site: I-69 sec3 seg12
Depth: 32 to 34 ft
Location: Daviess, IN
Soil IV
LOI = 2.3%
$CaCO_3$ = 2.9%

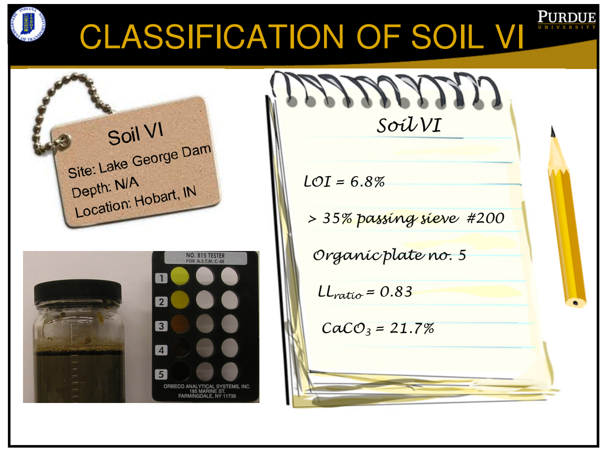

PURDUE
CLASSIFICATION OF SOIL V
Soil V
Site: N/A
Depth: N/A
Location: ASTM CL
Soil V
LOI = 3.6%
> 35% passing sieve no. 200
Organic plate no. 5
LL_{ratio} = 0.98
$CaCO_3$ = 4.2%

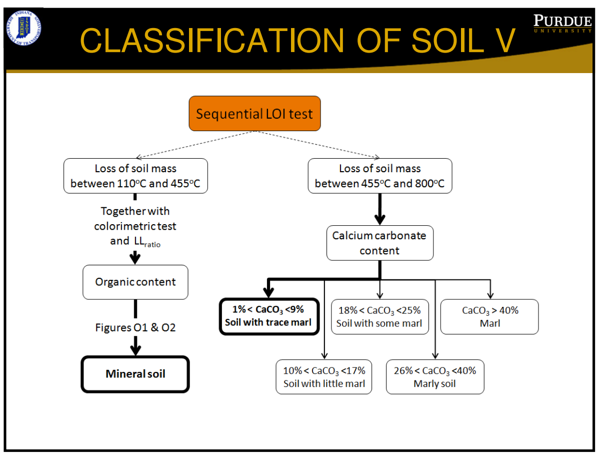

PURDUE
CLASSIFICATION OF SOIL IV
Sequential LOI test
Loss of soil mass between 110°C and 455°C
Loss of soil mass between 455°C and 800°C
Together with colorimetric test and LL_{ratio}
Organic content
Figures O1 & O2
Mineral soil
Calcium carbonate content
1% < $CaCO_3$ <9% Soil with trace marl
18% < $CaCO_3$ <25% Soil with some marl
$CaCO_3$ > 40% Marl
10% < $CaCO_3$ <17% Soil with little marl
26% < $CaCO_3$ <40% Marly soil

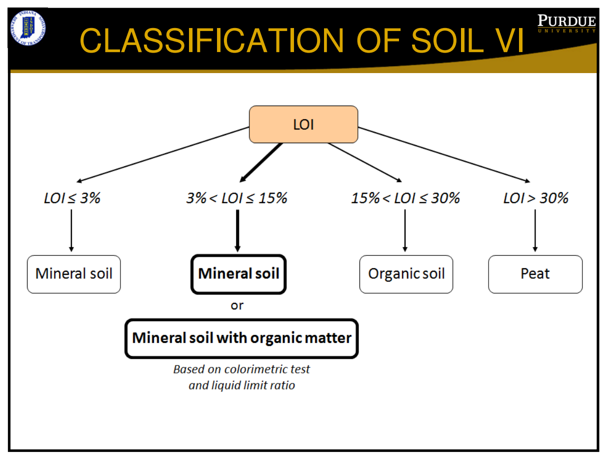

PURDUE
CLASSIFICATION OF SOIL V
LOI
LOI ≤ 3%
3% < LOI ≤ 15%
15% < LOI ≤ 30%
LOI > 30%
Mineral soil
Mineral soil
Organic soil
Peat
or
Mineral soil with organic matter
Based on colorimetric test and liquid limit ratio

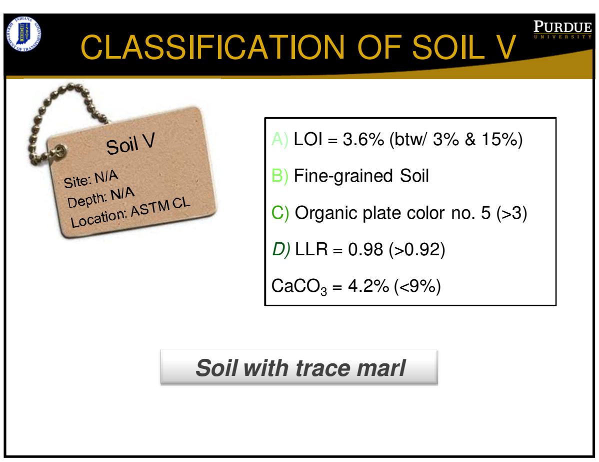
APPENDIX 1

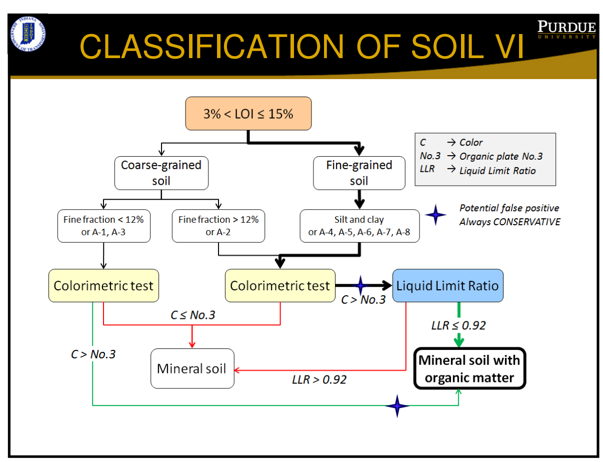

PURDUE
CLASSIFICATION OF SOIL V
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter


PURDUE
CLASSIFICATION OF SOIL VI
Soil VI
Site: Lake George Dam
Depth: N/A
Location: Hobart, IN
Soil VI
LOI = 6.8%
> 35% passing sieve #200
Organic plate no. 5
LL_{ratio} = 0.83
$CaCO_3$ = 21.7%

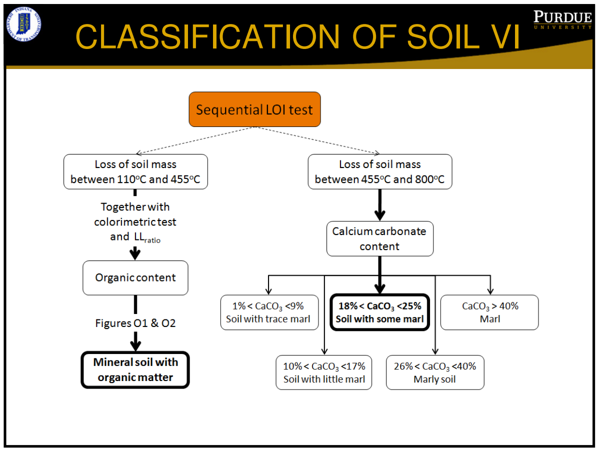

PURDUE
CLASSIFICATION OF SOIL V
Sequential LOI test
Loss of soil mass between 110°C and 455°C
Loss of soil mass between 455°C and 800°C
Together with colorimetric test and LL_{ratio}
Calcium carbonate content
Organic content
1% < $CaCO_3$ <9% Soil with trace marl
18% < $CaCO_3$ <25% Soil with some marl
$CaCO_3$ > 40% Marl
Figures O1 & O2
Mineral soil
10% < $CaCO_3$ <17% Soil with little marl
26% < $CaCO_3$ <40% Marly soil

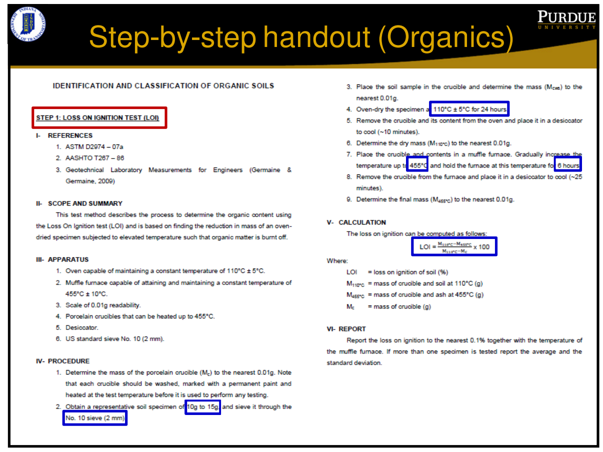

PURDUE
CLASSIFICATION OF SOIL VI
LOI
LOI ≤ 3%
3% < LOI ≤ 15%
15% < LOI ≤ 30%
LOI > 30%
Mineral soil
Mineral soil
Organic soil
Peat
or
Mineral soil with organic matter
Based on colorimetric test and liquid limit ratio

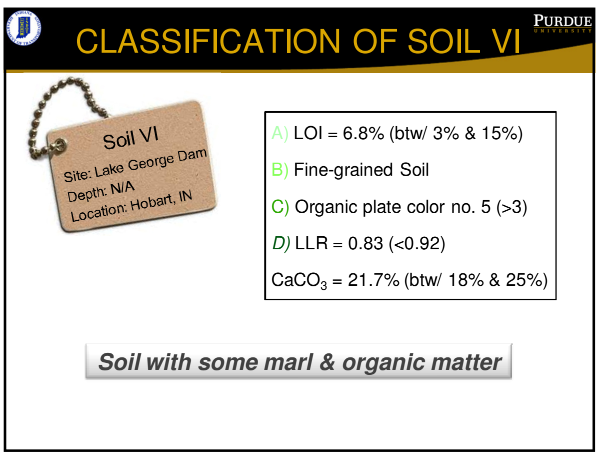

PURDUE
CLASSIFICATION OF SOIL V
Soil V
Site: N/A
Depth: N/A
Location: ASTM CL
A) LOI = 3.6% (btw/ 3% & 15%)
B) Fine-grained Soil
C) Organic plate color no. 5 (>3)
D) LLR = 0.98 (>0.92)
$CaCO_3$ = 4.2% (<9%)
Soil with trace marl

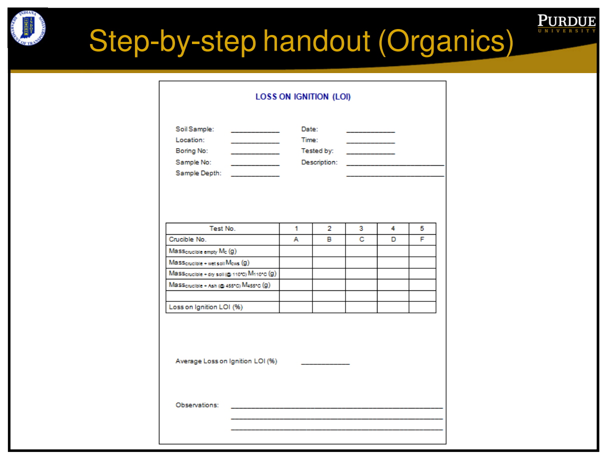

PURDUE
CLASSIFICATION OF SOIL VI
3% < LOI ≤ 15%
Coarse-grained soil
Fine-grained soil
C → Color
No.3 → Organic plate No.3
LLR → Liquid Limit Ratio
Fine fraction < 12% or A-1, A-3
Fine fraction > 12% or A-2
Silt and clay or A-4, A-5, A-6, A-7, A-8
Potential false positive
Always CONSERVATIVE
Colorimetric test
Colorimetric test
Liquid Limit Ratio
C > No.3
C ≤ No.3
LLR ≤ 0.92
C > No.3
Mineral soil
LLR > 0.92
Mineral soil with organic matter

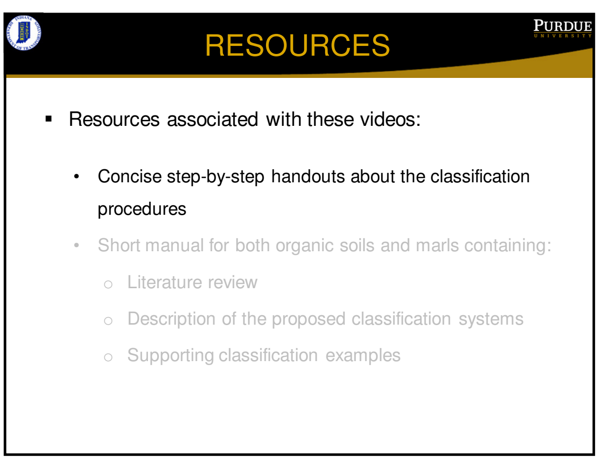
APPENDIX 1

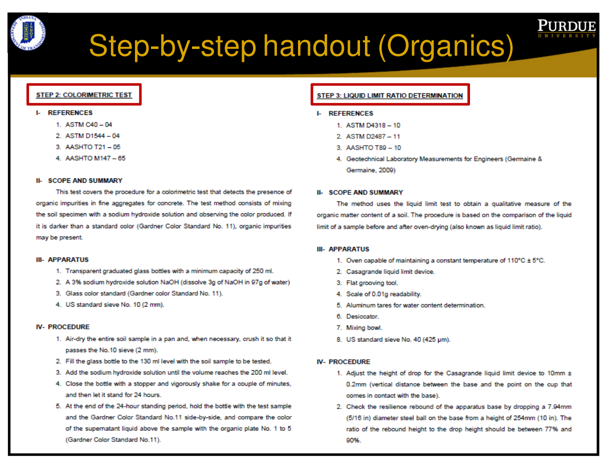

CLASSIFICATION OF SOIL VI
PURDUE UNIVERSITY
Sequential LOI test
Loss of soil mass between 110°C and 455°C
Loss of soil mass between 455°C and 800°C
Together with colorimetric test and LL_{ratio}
Organic content
Figures O1 & O2
Mineral soil with organic matter
Calcium carbonate content
1% < $CaCO_3$ <9% Soil with trace marl
18% < $CaCO_3$ <25% Soil with some marl
$CaCO_3$ > 40% Marl
10% < $CaCO_3$ <17% Soil with little marl
26% < $CaCO_3$ <40% Marly soil


Step-by-step handout (Organics)
PURDUE UNIVERSITY
IDENTIFICATION AND CLASSIFICATION OF ORGANIC SOILS
STEP 1: LOSS ON IGNITION TEST (LOI)
I- REFERENCES
II- SCOPE AND SUMMARY
III- APPARATUS
IV- PROCEDURE
V- CALCULATION
VI- REPORT

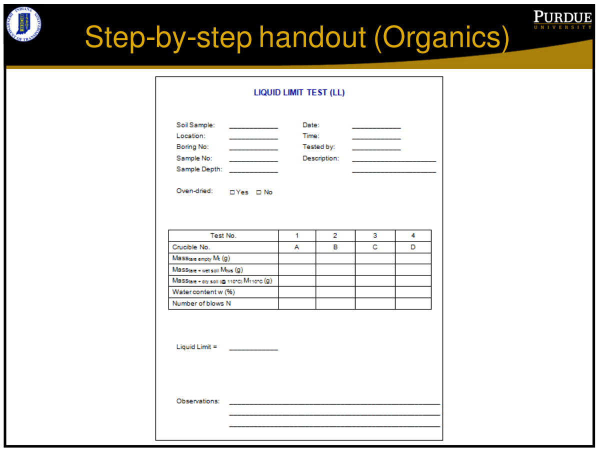

CLASSIFICATION OF SOIL VI
PURDUE UNIVERSITY
Soil VI
Site: Lake George Dam
Depth: N/A
Location: Hobart, IN
A) LOI = 6.8% (btw/ 3% & 15%)
B) Fine-grained Soil
C) Organic plate color no. 5 (>3)
D) LLR = 0.83 (<0.92)
$CaCO_3$ = 21.7% (btw/ 18% & 25%)
Soil with some marl & organic matter


Step-by-step handout (Organics)
PURDUE UNIVERSITY
LOSS ON IGNITION (LOI)
Soil Sample:
Location:
Boring No:
Sample No:
Sample Depth:
Date:
Time:
Tested by:
Description:
Test No.
Crucible No.
Loss on Ignition LOI (%)
Average Loss on Ignition LOI (%)
Observations:

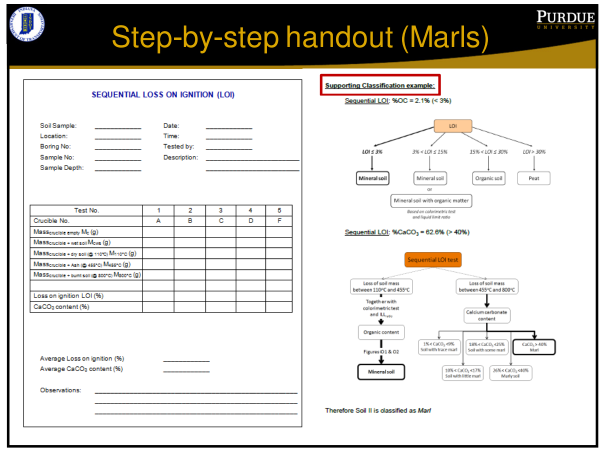

RESOURCES
PURDUE UNIVERSITY
Resources associated with these videos:
Concise step-by-step handouts about the classification procedures
Short manual for both organic soils and marls containing:
Literature review
Description of the proposed classification systems
Supporting classification examples


Step-by-step handout (Organics)
PURDUE UNIVERSITY
STEP 2: COLORIMETRIC TEST
STEP 3: LIQUID LIMIT RATIO DETERMINATION
I- REFERENCES
II- SCOPE AND SUMMARY
III- APPARATUS
IV- PROCEDURE

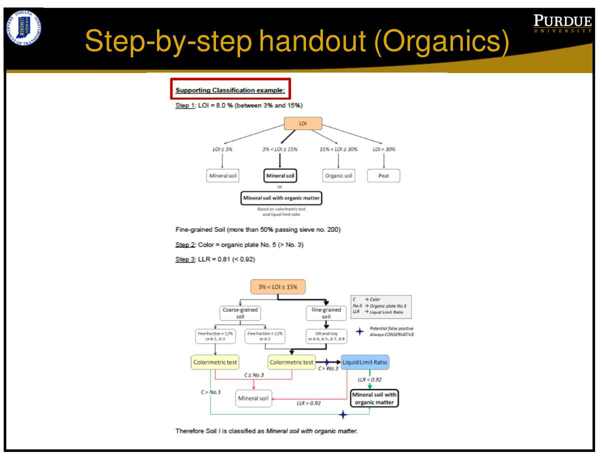
APPENDIX 1



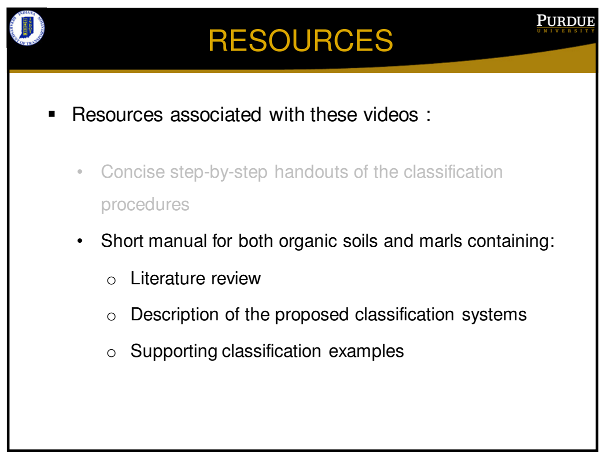
PURDUE
Step-by-step handout (Organics)
LIQUID LIMIT TEST (LL)



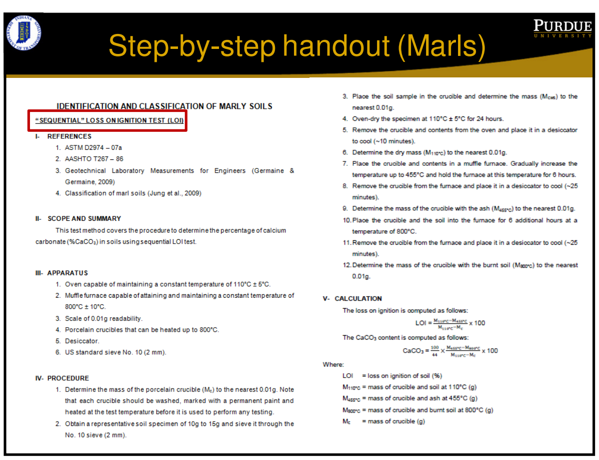
PURDUE
Step-by-step handout (Marls)
SEQUENTIAL LOSS ON IGNITION (LOI)
Supporting Classification example:



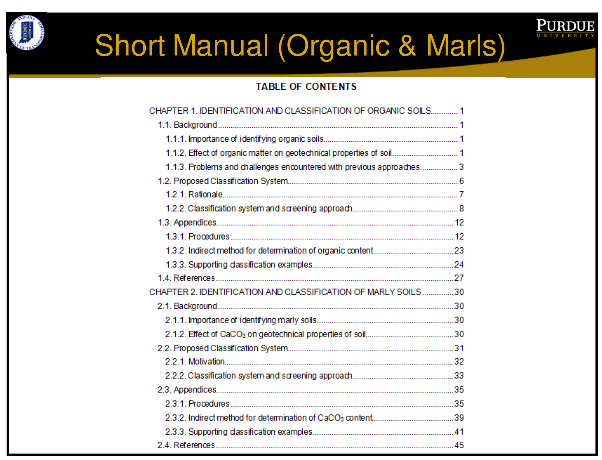
PURDUE
Step-by-step handout (Organics)
Supporting Classification example:



PURDUE
RESOURCES
Resources associated with these videos :
Concise step-by-step handouts of the classification procedures
Short manual for both organic soils and marls containing:
Literature review
Description of the proposed classification systems
Supporting classification examples



PURDUE
Step-by-step handout (Marls)
IDENTIFICATION AND CLASSIFICATION OF MARLY SOILS
"SEQUENTIAL" LOSS ON IGNITION TEST (LOI)



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Training PowerPoint

Acknowledgements

- Presentation prepared as part of SPR-3517,
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Thank you!

APPENDIX 2

Lab Manual

Project Implementation:

Classification of Organic Soils and Classification of Marls Training of INDOT Personnel

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This manual summarizes the methods and procedures developed for the classification of organic and marly soils by researchers at Purdue University. This work was conducted as part of two research projects funded through the Joint Transportation Program (SPR: 3005 - Classification of organic soils; SPR: 3227 – Classification of marl soils). The methods have been incorporated in INDOT standard specification 903.05 and 903.06 respectively. Development of the manual and of the accompanying training material has been funded through JTRP under SPR: 3517.

CHAPTER 1. IDENTIFICATION AND CLASSIFICATION OF ORGANIC SOILS

1.1. Background

1.1.1. Importance of identifying organic soils

From a geotechnical engineering perspective the presence of organic matter in soils can often represent a concern due to its negative influence on the mechanical properties. The presence of organic matter is generally associated with higher compressibility and creep, often unsatisfactory strength characteristics, as well as interference of organic constituents with soil stabilization reactions. These concerns pertain not only to peats and highly organic soils, but may apply also to soils with relatively low (<10%) values of organic content. For this reason many agencies have strict limits on the maximum allowable organic content in subgrade soils and backfills, requiring that it falls below threshold values in the 2-7% range *(1)*. The threshold value used by INDOT, standard specification 207.03 *(2)*, is 3% organic content.

1.1.2. Effect of organic matter on geotechnical properties of soils

It is recognized that the presence of organic matter plays a critical role in affecting both the geotechnical index properties and engineering properties of soils. Its effects can be summarized as follows:

1. Water content: Organic soils usually have very high water content. A more fibrous structure and/or a higher organic content result in large voids and the high cation exchange capacity of organic matter increases the attraction of water molecules; both characteristics result in high water content.
2. Gas content: The gas content of a soil is a very important parameter, which can change with time. The gas content influences permeability, consolidation rate,

and pore pressure generation *(3)*. Organic matter may undergo chemical decomposition which is accompanied by the production of marsh gas with small amounts of nitrogen and carbon dioxide.

3. Bulk density: Typically, soils with higher organic content have low bulk density, especially when the fiber content is high (i.e. low degree of decomposition).
4. Specific gravity: The specific gravity of a soil tends to decrease as the organic content increases. Values of specific gravity less than 2.0 are an indication of a soil with high organic content *(4)*.
5. Atterberg limits: In general both liquid limit and plastic limit increase with organic content due to the higher water adsorption capacity of organic matter.
6. Shrinkage potential: Shrinkage can be significant in soils with high organic content. For loose high organic soils, the volume change can reach 70% of their initial volume upon drying.
7. Compaction behavior: The maximum dry density decreases with organic content and the optimum moisture content increases as the organic content increases.
8. Strength: The strength of organic soils strongly depends on the organic content. As the organic content increases, the strength quickly decreases. However, the fibers in the soil (the fiber content is related to the degree of humification, i.e. decomposition of the soil), may produce a reinforcing effect on the soil matrix increasing the shear strength of the soil.
9. Permeability: The permeability of organic soils is much higher than inorganic soils. For example, the permeability of an organic soil with more than 75% organic content is 100 to 1000 times larger than typical values for inorganic clays. However, organic soils exhibit large deformations induced by creep. As a result the pore space in the soil may be drastically reduced with time, resulting in a dramatic decrease of permeability.
10. Compressibility: Peats and organic soils exhibit a much higher compressibility than other geotechnical materials *(5)*. First, organic soils have much higher natural water content and void ratio than inorganic soils; and second, organic soils have the highest values of C_α/C_c *(6, 7)*, which results in very high secondary consolidation (creep) deformations.

In summary, the geotechnical properties of organic soils depend on the following factors: 1) organic content; 2) type of organic matter; 3) degree of decomposition of the organic matter; and 4) void ratio. In general, as the organic content increases, water content, Atterberg limits, cation exchange capacity, and acidity all increase, whereas specific gravity, bulk density, plastic index, and efficiency of compaction decrease. In addition to organic content, the type of organic matter and the degree of decomposition of organic matter are two critical factors affecting the strength, permeability, and compressibility of organic soils. A more fibrous structure and a lower degree of decomposition usually lead to higher permeability and compressibility. The strength of an organic soil is reduced with the presence of organic matter; however, a fibrous structure, if present, may increase the shear strength and provide some tensile strength capacity. The void ratio depends on organic content, type of organic matter and degree of decomposition: a more fibrous structure, a higher organic content, and a lower degree of decomposition all lead to a more open structure, i.e. an increased void ratio. The void ratio controls the major properties of organic soils, especially compressibility. Their short, but large, primary consolidation and large secondary consolidation (creep) tend to create problems in civil engineering practice when organic soils are present.

1.1.3. Problems and challenges encountered with previous approaches

Methods previously used in practice for the identification of organic soils and for the quantification of organic matter have shortcomings when applied to soils with organic matter content less than ~10%. For such soils 1) the loss on ignition LOI often overestimates the true organic content, and 2) the criteria employed by the ASTM and ASHTO classification systems are generally insensitive to the presence of modest amounts of organic matter.

1.1.3.1. Inaccuracy of LOI test for measuring true organic content

The loss on ignition (LOI) test is the method most commonly employed in practice for assessing organic content, and measurements of the LOI are routinely conducted to establish the suitability of a soil as a subgrade material and decide on the need for soil removal or treatment. Despite the simplicity and cost effectiveness of the LOI test, heating temperature and duration can significantly affect its results, and the presence of a number of inorganic constitutes (e.g. some hydrated alluminosilicates, gypsum) can lead to overestimate the soil's true organic content. The error can be especially significant in soils with organic content <10% *(8, 9)*, potentially requiring unnecessary and costly operations of soil excavation and removal, or soil modification/stabilization.

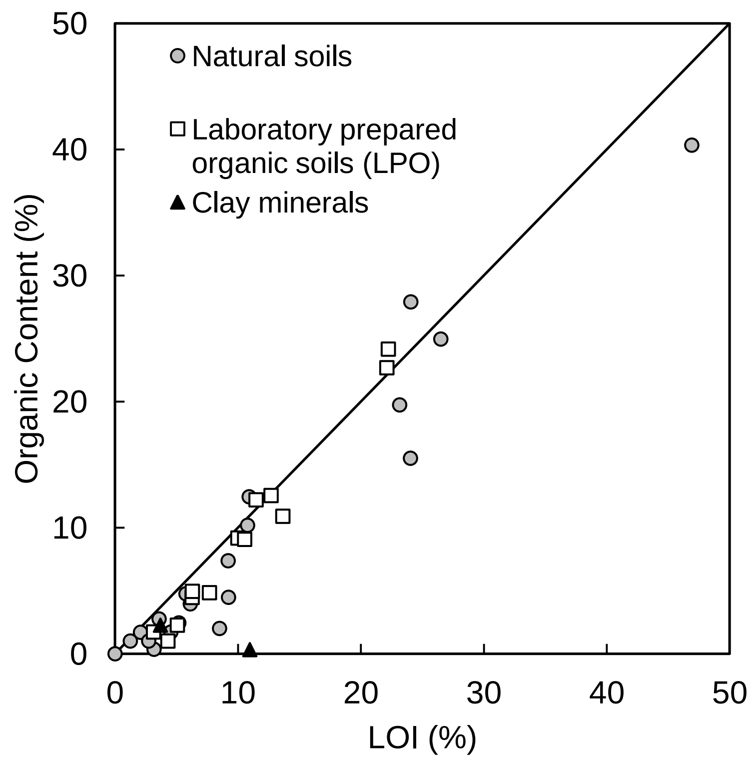

Figure 1-1 : Loss on ignition versus organic content *(10)*

Measurements of the organic matter content obtained from the results of the dry combustion analysis, and herein considered representative of the "true" organic content of the soil are compared to the LOI data in Figure 1-1. The data presented in Table 1-1 and Figure 1-1 show that the LOI test may significantly overestimate the true organic content of some soils, particularly for low values of the organic content. This is clearly an important concern if the loss on ignition method is to be used to identify and screen soils. For example, based on the LOI test, soils 1, 4, and 9 would not be considered adequate for use as subgrade soils in the State of Indiana, which employs a maximum threshold value for the organic content of 3%. The measurement of the true organic content using the dry combustion analysis shows instead that all three are viable subgrade geomaterials.

Table 1-1: Summary of test results for natural soils *(10)*

Soil ID	**Classification (ASTM D2487)**	**LL**	**PL**	**PI**	**Liquid Limit Ratio**	**Colorimetric Test Result**	**Organic Content**	**LOI**
	n/a	**%**	**%**	**%**	**n/a**	**No.**	**%**	**%**
Soil 1	CL	49.0	27.2	21.8	0.96	1	0.4	3.2
Soil 2	ML	36.9	28.0	8.9	0.93	3	1.7	2.1
Soil 3	ML	31.2	23.6	7.5	0.97	3	2.8	3.6
Soil 4	ML	46.7	35.0	11.6	0.88	3	2.4	5.2
Soil 5	CL	32.1	20.1	12.0	0.98	1+	1.0	1.2
Soil 6	ML	-	-	-	-	<1	0.0	0.0
Soil 7	OL	47.7	38.6	9.1	0.68	5	12.5	10.9
Soil 8	ML	41.7	33.8	7.8	0.85	4	4.8	5.8
Soil 9	CL	34.0	14.7	19.3	1.00	4	1.7	4.5
Soil 10	CH	60.5	19.3	41.2	0.99	1+	1.0	2.7
Soil 11	OH	151.1	123.0	28.1	0.58	-	38.5	43.2
Soil 12	MH	79.5	57.8	21.7	0.77	5	27.9	24.1
Soil 13	MH	94.2	67.4	26.8	0.79	4+	19.7	23.2
Soil 14	MH	112.8	58.9	53.8	0.87	4	15.5	24.0
Soil 15	MH	121.7	62.6	59.1	0.86	4	10.2	10.8
Soil 16	OH	117.7	82.4	35.3	0.55	-	25.0	26.5
Soil 17	ML	39.1	25.2	13.9	0.96	4	4.0	6.1
Soil 18	MH	73.5	42.7	30.8	0.77	3	7.4	9.2
Soil 19	CL	48.6	25.1	23.5	0.82	3+	2.0	8.5
Soil 20	MH	67.2	39.9	27.3	0.92	5	4.5	9.2
Soil 21	MH	69.0	45.3	23.7	0.82	4	6.47	7.25
Soil 22	ML	48.0	32.3	15.7	0.80	3	0.00	2.71

1.1.3.2. Non-sensitivity of the ASTM and AASHTO classification systems to the presence of low organic matter

The Unified Soil Classification System *(11)* considers organic soils as a subgroup of fine-grained soils: silts and clays are classified as organic based on the reduction in liquid limit measured after oven drying the soil (if $LL_{oven\ dried}/LL_{non\ dried} < 0.75$, a clay or a silt is termed organic and denoted as OL or OH depending on whether the LL is smaller or greater than 50). While there is no doubt that the presence of organic matter markedly affects the LL, the criterion does not discriminate between different levels of organic, and is not consistently sensitive to the presence of <10% amounts of organic matter. Note that ASTM D2487-10 *(11)* also considers highly organic soils, which it terms peats. Such soils are classified based on the prevalence of organic matter, their dark color and organic odor. Similarly, the AASHTO classification system considers only highly organic soils (peat or muck), which are included in group A-8, and classified based solely on visual inspection. The AASHTO system does not consider the impact of organic matter in any of the other groups.

For example, Table 1-1 shows that soils 8, 12, 13, 14, 15, 17, 18, 20, and 21 have a liquid limit ratio larger than 0.75. Thus they are classified as non organic soils according to ASTM D2487-10 *(11)*. However, all these soils have organic content higher than 3% (and as high as 27.9%) and they would not be considered viable subgrade soils in the State of Indiana.

1.2. New Classification System

Prior to the work conducted as part of SPR-3005, the identification and classification of organic soils within INDOT relied on the loss on ignition method. As discussed in the previous section, this method can lead to incorrect classification of soils, especially given the strict guidelines on organic content used by INDOT to determine the acceptability of a soil for a given application (e.g. <3% for a subgrade soil). This, in turn, may lead to erroneously considering a material unviable for a given application, and generate unnecessary costs for material replacement/treatment. The new classification system, developed as part of SPR-3005 is a four tier-classification that is based on the combined results of three different tests: loss on ignition (LOI), colorimetric test, and liquid limit ratio determination. It replaces the previous INDOT classification system, INDOT standard specification 903.05 *(2)*, which relied on 5 tiers and was based exclusively on the result of the LOI test. Table 1-2 summarizes the four different categories for organic soils classification in the new classification system. Soils with organic content less than or equal to 3% are termed *mineral soils*. If the organic content is greater than 3% and less than or equal to 15%, soils are classified as *mineral soils with organics*. Once the organic content falls in the 15%-30% range, the term *organic soils* is employed. Finally, soils with organic content higher than 30% are termed *highly organic soils* or *peats*.

Table 1-2: Criteria of organic soils classification *(10)*

Classification	**Organic Content OC (%)**
Mineral soils*	OC ≤ 3%
Mineral soils* with organics	3% < OC ≤ 15%
Organic soils	15% < OC ≤ 30%
Highly organic soils or Peats	OC >30%

* “Mineral soils” designated through USCS/AASHTO terminology

1.2.1. Rationale

The rationale for the new classification system can be summarized as follows:

1. Soils with organic content less than 3% are usually considered as mineral soils in most existing classification systems, as the presence of 3% or less organic matter does not significantly change the soil’s properties. Also, the Indiana specifications for roadway construction section 207.03 *(2)* require that *“soils containing greater than 3% by dry weight calcium, magnesium carbonate or organic material [as determined based on the loss on ignition test in AAHSTO T267]… will not be permitted within the specified thickness of the subgrade*”. Therefore, 3% of organic content is an acceptable boundary for mineral soils.
2. The results of the Atterberg limit tests conducted by Huang et al. *(10)* show that when the liquid limit ratio is smaller than 0.75, the organic content of the given soil is around 15-18% (see Figure 1-2). Thus, soil with organic content less than

15% would be classified as inorganic based on the USCS. This is the basis for using a 15% organic content as a means to distinguish between organic soils and mineral soils with organic matter.

3. 30% of organic content is adopted to be the boundary between organic soil and highly organic soil (Peat) in many currently existing classification systems such as the Canadian System of Soil Classification (CSSC), as well as in the criteria previously used by INDOT *(2)*.

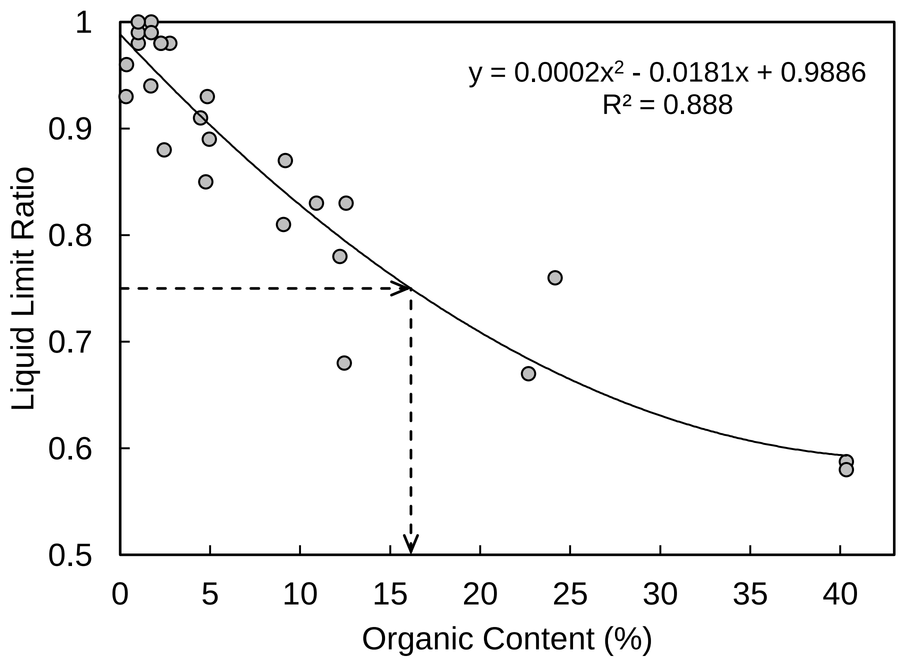

Figure 1-2: Liquid limit ratio versus organic content *(10)*

1.2.2. Classification system and screening approach

Figure 1-3 presents the recommended test procedure for classifying soils based on organic content in form of a flow chart. The LOI test is used first to provide a first assessment of the organic content. Figure 1-3 shows that based on the outcome of the LOI test it is possible to classify the soils in one of the four categories outlined above with the only uncertainty remaining in the case in which the LOI falls in the 3-15% range. In this case, the LOI may potentially overestimate the soil's true organic content and thus an alternative screening approach based on the use of the colorimetric test and/or the liquid limit test is proposed.

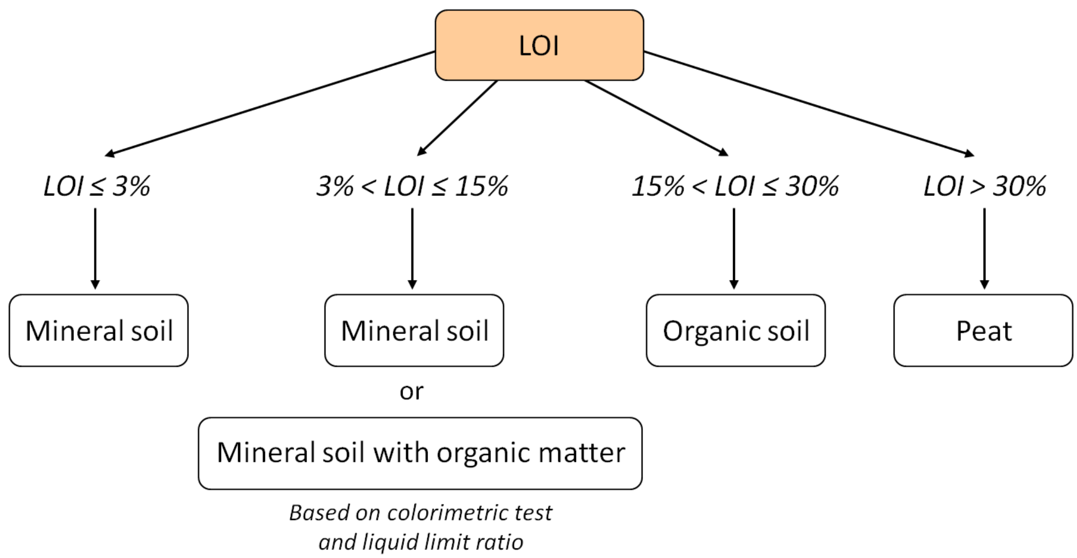

Figure 1-3: Soil classification based on organic content in revised classification system *(10)*

This second screening is summarized in Figure 1-4: for coarse-grained soil with fine fraction (i.e. passing #200 sieve) less than 12%, the colorimetric test is performed. If the color is lighter or equal to the organic plate No.3, the soil is considered to have negligible organic content, i.e. it is concluded that the LOI test overestimates the true organic content of the soil, which can be considered a mineral soil. Reliance on the results of the colorimetric test is based on the sensitivity of this test to the presence of organic matter in coarse-grained soils.

For fine soils and coarse soils with fine fraction greater than 12%, the colorimetric test also follows the LOI determination. If the color is lighter or equal than the organic plate No.3, the same conclusion as above is drawn, i.e. the soil is classified as a mineral soil. If the color is darker than No. 3 the screening process may be terminated if it is deemed acceptable that false positives may occur (i.e. that a soil may be erroneously considered as having organic content greater than 3%). If this not considered acceptable, the LL ratio is determined as a means to correct for these false positive results. Provided that the LL ratio is smaller than a given critical value (denoted in Figure 1-4 as LL_{crit}), it can be concluded that a soil's organic content is higher than a threshold value of 3%. Based on the data for Indiana soils collected as part of SPR-3005, a value of LL_{crit} equal to 0.92 is recommended (see Figure 1-2).

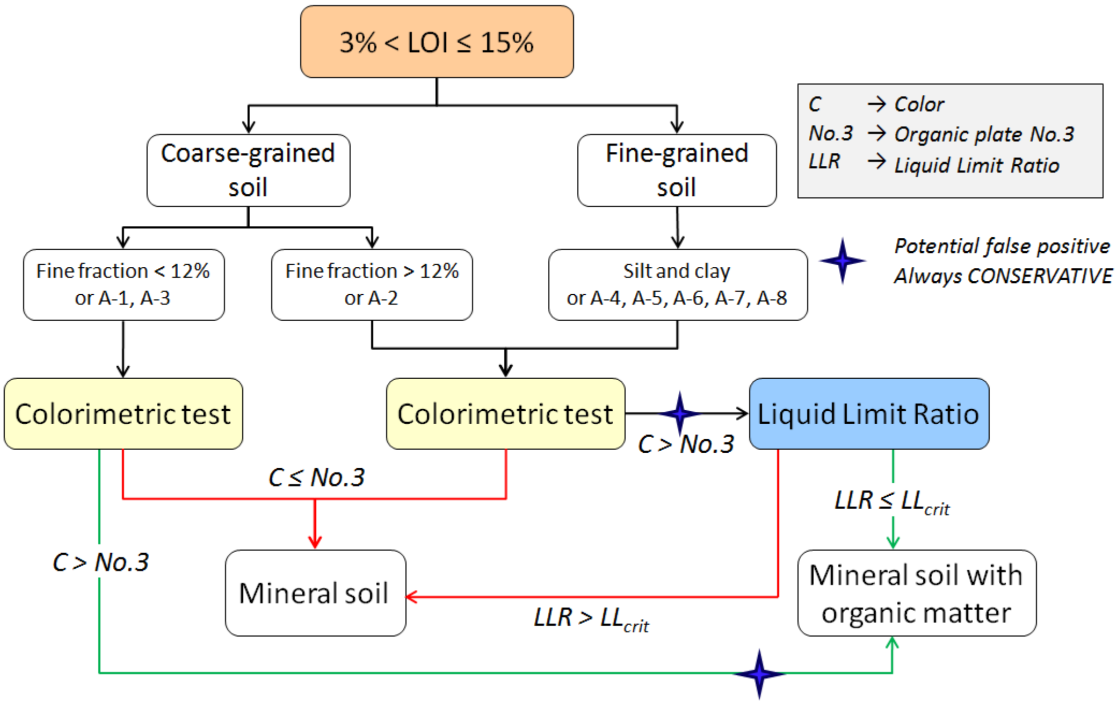

Figure 1-4: Approach for the classification of soils with 3% < LOI ≤ 15% *(10)*

When classification of the soil is not required, and a preliminary assessment of the presence of organic matter in a soil is required, the colorimetric test may be used as a "screening tool." In this case, the test provides a "yes"/"no" answer, i.e. if the color is less or equal than no.3, the soil can be assumed to have negligible organic content. If, instead, the color is greater than no. 3, it can be concluded that the organic content is likely to exceed 3%. Based on the data for Indiana soils examined as part of SPR-3005, no false negatives were observed (i.e. all organic soils were successfully detected). However, the method can generate false positives (i.e. color > no. 3 even for negligible % of organic matter), which may be resolved using the full procedure outlined in Figure 1-3 and Figure 1-4. Use of this screening method in coarse soils is discouraged.

1.3. Appendices

1.3.1. Procedures

1.3.1.1. Loss on Ignition Test (LOI)

a. References

1. Standard test methods for moisture, ash, and organic matter of peat and other organic soils (ASTM D2974 – 07a) *(12)*
2. Standard method of test for determination of organic content in soils by loss on ignition (AASHTO T267 – 86) *(13)*
3. Geotechnical Laboratory Measurements for Engineers (Germaine & Germaine, 2009) *(14)*

b. Scope and Summary

This test method describes the process to estimate the organic content using the loss on ignition test (LOI) and is based on finding the reduction in mass of an oven-dried specimen subjected to elevated temperature such that organic matter is burnt off.

c. Background

Organic content can be determined using different methods. The LOI test is straightforward and is typically used in geotechnical laboratories. It measures the loss of mass by ignition when an oven-dried specimen (110°C) is placed in a furnace at much higher temperature (455°C), and assumes that this mass loss is entirely due to the oxidation of organic matter. Estimates of the organic content obtained from the LOI test usually exceed the true organic content because other processes (e.g. the dedydroxilation of some clay minerals) may be responsible for loss of mass at elevated temperatures. A more accurate method for determining the true organic content is the dry combustion test (see section 1.3.2).

d. Apparatus

1. Oven capable of maintaining a constant temperature of 110°C ± 5°C.
2. Muffle furnace capable of attaining and maintaining a constant temperature of 455°C ± 10°C.
3. Scale with 0.01g readability.
4. Porcelain crucibles that can be heated up to 455°C.
5. Desiccator.
6. US standard sieve No. 10 (2 mm).

e. Procedure

1. Determine the mass of the porcelain crucible (M_c) to the nearest 0.01g. Note that each crucible should be washed, marked with a permanent paint and heated at the test temperature before it is used to perform any test.
2. Obtain a representative soil specimen of 10g to 15g, and sieve it through the No. 10 sieve (2 mm) *(13)*.
3. Place the soil sample in the crucible and determine the mass (M_{cws}) to the nearest 0.01g.
4. Oven-dry the specimen at 110°C ± 5°C for 24 hours (or until no mass loss is observed).
5. Remove the crucible and its content from the oven and place it in a desiccator to cool (~10 minutes).
6. Determine the dry mass ($M_{110°C}$) to the nearest 0.01g.
7. Place the crucible and contents in a muffle furnace at 455°C for 6 hours.
8. Remove the crucible from the furnace and place it in a desiccator to cool (~25 minutes).
9. Determine the final mass ($M_{455°C}$) to the nearest 0.01g.

f. Calculation

The loss on ignition is computed as follows:

$$LOI = \frac{M_{110°C} - M_{455°C}}{M_{110°C} - M_c} \times 100$$

Where:

LOI = loss on ignition of soil (%)

$M_{110°C}$ = mass of crucible and soil at 110°C (g)

$M_{455°C}$ = mass of crucible and ash at 455°C (g)

M_c = mass of crucible (g)

g. Report

Report the organic content to the nearest 0.1% together with the temperature of the muffle furnace. If more than one specimen is tested, report the average and the standard deviation of the values.

LOSS ON IGNITION (LOI) – Sample Sheet

Soil Sample: Soil I
Location: I69-Sec3 Seg13
Boring No: 3-31-TB-2A
Sample No:
Sample Depth: 30 to 32ft (Bottom)

Date: Sat 10/22/2011
Time: 11:00am
Tested by: AH
Description: Black - silty
455 (6hrs) 800(6hrs)

Test No.	1	2	3	4	5
Crucible No.	A	B	C	D	F
$Mass_{crucible\ empty}$ M_c (g)	17.67	17.94			
$Mass_{crucible\ +\ wet\ soil}$ M_{cws} (g)	34.29	32.80			
$Mass_{crucible\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	30.02	28.44			
$Mass_{crucible\ +\ Ash\ (@\ 455°C)}$ $M_{455°C}$ (g)	29.20	27.47			
Loss on Ignition LOI (%)	*6.6*	*9.3*			

Average Loss on Ignition LOI (%) ____8.0_____

Observations: ____

LOSS ON IGNITION (LOI)

Soil Sample: ____________ Date: ____________
Location: ____________ Time: ____________
Boring No: ____________ Tested by: ____________
Sample No: ____________ Description: ____________
Sample Depth: ____________ ____________

Test No.	1	2	3	4	5
Crucible No.	A	B	C	D	F
$\text{Mass}_{\text{crucible empty}}$ M_c (g)					
$\text{Mass}_{\text{crucible + wet soil}}$ M_{cws} (g)					
$\text{Mass}_{\text{crucible + dry soil (@ 110°C)}}$ $M_{110°C}$ (g)					
$\text{Mass}_{\text{crucible + Ash (@ 455°C)}}$ $M_{455°C}$ (g)					
Loss on Ignition LOI (%)					

Average Loss on Ignition LOI (%) ____________

Observations: ____________

1.3.1.2. Colorimetric test

a. References

1. Standard test method for organic impurities in fine aggregates for concrete (ASTM C40 – 04) *(15)*
2. Standard test method for color of transparent liquids (Gardner color scale) (ASTM D1544 – 04) *(16)*
3. Standard method of test for organic impurities in fine aggregates for concrete (AASHTO T21 – 05) *(17)*
4. Standard specification for materials for aggregate and soil-aggregate subbase, base, and surface courses (AASHTO M147 – 65) *(18)*

b. Scope and Summary

This test covers the procedure for a colorimetric test that detects the presence of organic impurities in soils. The test method consists of mixing the soil specimen with a sodium hydroxide solution and observing the color produced. If it is darker than a standard color (Gardner Color Standard No. 11), organic impurities may be present.

c. Background

The colorimetric test is one of several techniques that can be used to derive information on the presence of organic matter but without necessarily providing a quantitative assessment of the organic content of a soil. The test shows great sensitivity to the presence of organic matter in both fine and coarse soils. The colorimetric test is a relatively easy, economic and not time consuming method. However, the test can lead to false positives (i.e. the supernatant can turn dark even though no organic matter is present). It is recommended to use this technique in conjunction with other tests (e.g. LOI, liquid limit ratio) in order to identify organic content.

d. Apparatus

1. Transparent graduated glass bottles with a minimum capacity of 250 ml.
2. A 3% sodium hydroxide solution NaOH (dissolve 3g of NaOH in 97g of water)
3. Glass color standard (Gardner color Standard No. 11).
4. US standard sieve No. 10 (2 mm).

e. Procedure

1. Air-dry the entire soil sample in a pan and, when necessary, crush it so that it passes the No.10 sieve (2 mm) (the opening size of the No.10 sieve (2mm) corresponds to the definition of fine aggregate according to AASHTO M147 – 65 *(18)*).
2. Fill the glass bottle to the 130 ml level with the soil sample to be tested.
3. Add the sodium hydroxide solution until the volume reaches the 200 ml level.
4. Close the bottle with a stopper and vigorously shake for a couple of minutes, and then let it stand for 24 hours.
5. At the end of the 24-hour standing period, hold the bottle with the test sample and the Gardner Color Standard No.11 side-by-side, and compare the color of the supernatant liquid above the sample with the organic plate No. 1 to 5 (Gardner Color Standard No.11). Note that it is very critical to read the color after 24 hours since some soils show a light color few hours after adding the NaOH solution and darker after 24 hours (see Figure 1-5).

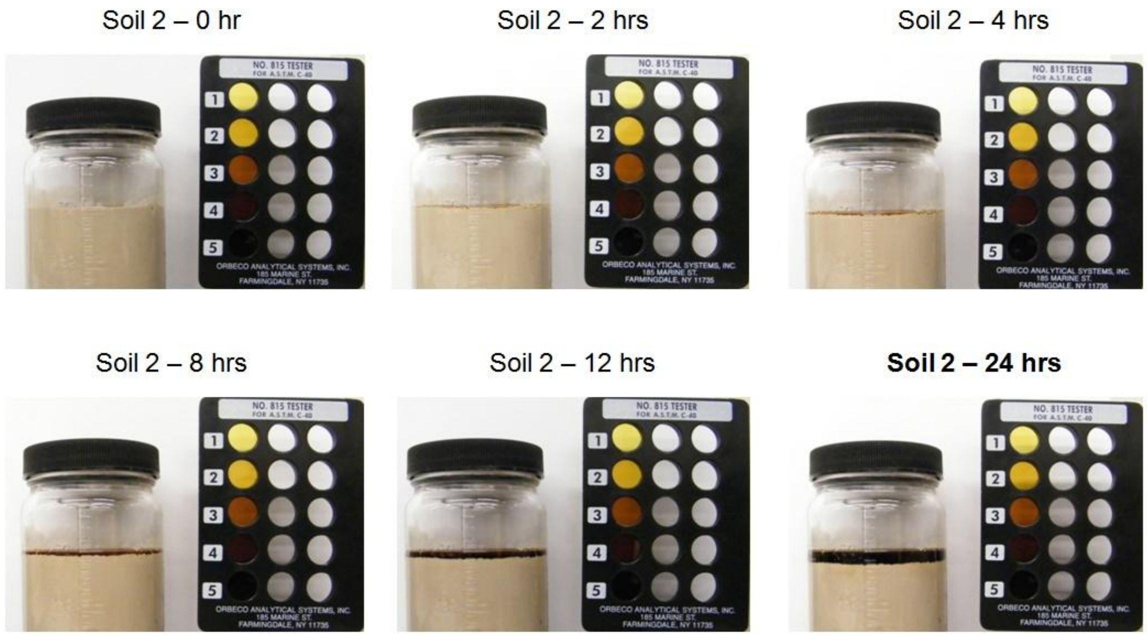

Figure 1-5 : Colorimetric test at different times after adding the NaOH solution

f. Report

Report the organic plate number which is closest to the color of the supernatant. The color depends on the presence of organic matter. Specifically, according to the standard, “if the color of the supernatant liquid is darker than that of the standard color of solution or the glass color standard organic plate No. 3 (Gardner Color Standard No.11), the fine aggregate under test shall be considered to possibly contain injurious organic impurities”.

1.3.1.3. Liquid limit ratio determination

a. References

1. Standard test methods for liquid limit, plastic limit, and plasticity index of soils (ASTM D4318 – 10) *(19)*
2. Standard practice for classification of soils for engineering purposes (Unified Soil Classification System) (ASTM D2487 – 10) *(11)*
3. Standard method of test for determining the liquid limit of soils (AASHTO T89 – 10) *(20)*
4. Geotechnical Laboratory Measurements for Engineers (Germaine & Germaine, 2009) *(14)*

b. Scope and Summary

The method is based on the use of the liquid limit test to obtain a qualitative measure of the organic matter content of a soil. This can be obtained by comparing the liquid limit of a sample before and after oven-drying. The described method follows ASTM standard D4318 – 10 *(19)*. The only deviation from the standard is the order of performing the determination of the blow counts at various water contents: while the standard suggests a dry to wet procedure (i.e. water is added to the soil before each blow count determination), a wet to dry procedure (using a fan to dry the soil) is instead recommended. It is acknowledged that the two procedures may cause slight differences in the results of liquid limit; however, the use of the latter procedure is reported to generate more repeatable data *(14)*.

c. Background

The liquid limit of a soil is the water content at which the soil passes from a plastic to a liquid state. It is used for soil classification. In addition, a soil containing substantial amounts of organic matter shows a dramatic decrease in the liquid limit when oven-dried before testing. Therefore, a qualitative measure of organic content of a soil can be obtained by comparing the oven-dried liquid limit with the not oven-dried liquid limit. If the ratio (also known as liquid limit ratio) is less than 0.75, the soil is classified as an organic soil.

d. Apparatus

1. Oven capable of maintaining a constant temperature of 110°C ± 5°C.
2. Casagrande liquid limit device.
3. Flat grooving tool.
4. Scale of 0.01g readability.
5. Aluminum tares for water content determination.
6. Desiccator.
7. Mixing bowl.
8. US standard sieve No. 40 (425 μm).

e. Procedure

1. Adjust the height of drop for the Casagrande liquid limit device to 10mm ± 0.2mm (vertical distance between the base and the point on the cup that comes in contact with the base).
2. Check the resilience rebound of the apparatus base by dropping a 7.94mm (5/16 in) diameter steel ball on the base from a height of 254mm (10 in). The ratio of the rebound height to the drop height should be between 77% and 90%.
3. Sieve soil through US No. 40 sieve and obtain natural water content (never oven dry soil prior to tests).
4. Mix about 100 g of soil with distilled water to about 15 drop consistency, cover to prevent loss of moisture and place it in a humid room for 24 hours to temper.
5. Place soil in the Casagrande cup to a maximum depth of ½ inch. The soil should form a flat horizontal surface with the bottom lip of the cup. This can be checked by filling the cup on the strike position with water. Ensure that entrapped air is removed and that the flat surface is smooth.
6. Groove the soil with the flat grooving tool maintaining the tool perpendicular to the surface of the cup throughout its movement.

7. Lift and drop the cup by turning the crank at a rate of 2 blows/second until the groove closes for a length of 13 mm (½ inch) and record the number of blows.
8. Remove soil from cup and return to the dish. Wash and dry the cup and grooving tool and reattach the cup to the carriage in preparation for the next trial.
9. Mix soil in a dish and repeat steps 5, 6, 7 and 8 until two consistent blow counts (± 1) are measured.
10. Remove about 10 g of paste perpendicular and across the closed groove, place in a tare of known mass and put it in the oven (110°C ± 5°C) for water content measurements.
11. Obtain four separate water content determinations between 15 and 35 blows by drying the soil slightly and repeating steps 5 through 10.
12. Plot the water content against log of number of blows, draw the flow curve and select the liquid limit as the intersection of this curve and the 25 blow line.
13. Prepare another soil sample by working the material through the US No. 40 sieve and oven-dry it for 24 hours at 110°C ± 5°C (or until no mass loss is observed).
14. Repeat steps 4 through 12 and determine the oven-dried liquid limit.

f. Calculation

The liquid limit ratio is computed as follows:

$$LL_{ratio} = \frac{LL_{\text{oven dried}}}{LL_{\text{not dried}}}$$

Where:

LL_{ratio} = Liquid limit ratio

$LL_{\text{oven dried}}$ = Liquid limit for oven-dried soil

$LL_{\text{not dried}}$ = Liquid limit for not oven-dried soil

g. Report

Report the average liquid limits before and after oven-drying along with the standard deviation. Also, provide the liquid limit ratio and note whether the specimen is an organic or inorganic soil.

LIQUID LIMIT TEST (LL) – Sample Sheet

Soil Sample:	Soil I	Date:	Thu 10/27/2011
Location:	I69-Sec3 Seg13	Time:	11:30am
Boring No:	3-31-TB-2A	Tested by:	AH/MS
Sample No:		Description:	Black - silty
Sample Depth:	30 to 32ft (Bottom)		455 (6hrs) 800(6hrs)

Oven-dried: ☐ Yes ■ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
Mass$_{tare\ empty}$ M_t (g)	1.32	1.30	1.33	1.31
Mass$_{tare\ +\ wet\ soil}$ M_{tws} (g)	4.90	4.95	4.91	5.60
Mass$_{tare\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	3.57	3.63	3.62	4.07
Water content w (%)	*58.9*	*56.7*	*56.2*	*55.6*
Number of blows N	14	25	29	34

Liquid Limit = ____56.7%____

Observations: ______________________________

LIQUID LIMIT TEST (LL) – Sample Sheet

Soil Sample:	Soil I	Date:	Thu 10/27/2011
Location:	I69-Sec3 Seg13	Time:	11:30am
Boring No:	3-31-TB-2A	Tested by:	AH/MS
Sample No:		Description:	Black - silty
Sample Depth:	30 to 32ft (Bottom)		455 (6hrs) 800(6hrs)

Oven-dried: ■ Yes ☐ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
Mass$_{tare\ empty}$ M_t (g)	1.30	1.34	1.30	1.33
Mass$_{tare\ +\ wet\ soil}$ M_{tws} (g)	5.34	4.89	6.48	6.05
Mass$_{tare\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	4.03	3.77	4.86	4.59
Water content w (%)	*47.9*	*46.4*	*45.5*	*44.9*
Number of blows N	16	22	28	33

Liquid Limit = ____46.0%____

Observations: ______________________________

LIQUID LIMIT TEST (LL)

Soil Sample: ______________ Date: ______________

Location: ______________ Time: ______________

Boring No: ______________ Tested by: ______________

Sample No: ______________ Description: ________________________

Sample Depth: ______________ ________________________

Oven-dried: ☐ Yes ☐ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
Mass$_{\text{tare empty}}$ M_t (g)				
Mass$_{\text{tare + wet soil}}$ M_{tws} (g)				
Mass$_{\text{tare + dry soil (@ 110°C)}}$ $M_{110°C}$ (g)				
Water content w (%)				
Number of blows N				

Liquid Limit = ______________

Observations: ____

____

____

1.3.2. Indirect method for determination of organic content

a. *Basic principle*

An indirect method for the determination of organic content is based on measuring the concentration of total organic carbon (TOC) in soils. For any soil sample the organic content can be calculated by multiplying the total organic carbon content by a factor that reflects the carbon content of the soil's organic matter, which typically ranges between 48% and 58% (by weight) *(21)*. Thus, in principle, the correction factor is soil and horizon specific. In practice, a correction factor of 1.724 (based on the assumption that organic matter contains 58% organic C) has been traditionally used *(22)*. As shown in the equation below, this factor is used to estimate the true organic content.

$$OC\ (\%) = 1.724 \times C_{organic}\ (\%)$$

The total organic carbon (TOC) is determined by conducting the dry combustion test and the loss of carbon dioxide test as summarized in the next two subsections.

b. *Total carbon content (Dry combustion test)*

Dry combustion is considered to be the most reliable and accurate measurement of the total carbon content of a soil *(22)*. The test consists in oxidizing organic carbon and thermally decomposing other carbonate minerals at high temperature (~950ºC) in a resistance furnace. The total carbon content is then obtained through measurement of the CO_2 released from the elemental carbon. If there is no inorganic carbon, the total carbon provided by the dry combustion test is equal to the total organic carbon (TOC) of the soil. The potential presence of inorganic carbon can be assessed by pre-testing all soil samples by adding drops of a 3M hydrochloric acid (HCl) solution to a small soil sub-sample. If strong froth is observed, it is concluded that the soil contains inorganic carbon (e.g. calcite ($CaCO_3$) and/or dolomite ($CaMg(CO_3)_2$)), and an independent measure of the inorganic carbon content should be conducted using the procedure described in the following subsection. The total organic carbon content is then determined as the difference between the total carbon content given by the dry combustion test and the inorganic carbon content.

c. *Inorganic carbon content (Loss of carbon dioxide - Gravimetric method)*

This test is used to determine the inorganic carbon content of soils. The test consists of adding hydrochloric acid (HCl) to a soil sample and measuring the decrease in mass resulting from the release of CO_2 that is produced. Given that the release of CO_2 to the atmosphere is proportional to the carbonate content of the soil *(23)*, the latter can then be determined from the measured CO_2. A soil sample of about 1g is placed in a flask with 10 ml of 3M hydrochloric acid (HCl), and measurements of the mass of the flask are conducted every 15 minutes until the change in mass is less than 1-2 mg. The carbon content can then be calculated from the following:

$$C\ (\%) = [CO_{2\ lost}\ (g) / Soil\ (g)] \times 0.2727 \times 100$$

1.3.3. Supporting classification examples

This section contains examples of the classification of soils containing organic matter based on the system and testing procedures proposed in CHAPTER 1. The table below summarizes the following: liquid limit, plastic limit, plasticity index, loss on ignition, results of colorimetric test, liquid limit ratio, and the corresponding classification. Figure 1-6 to Figure 1-9 present the classification of four different soil samples based on the results of LOI, colorimetric test and liquid limit ratio.

Table 1-3: Supporting classification examples for organic soils

Soil ID	**LL**	**PL**	**PI**	**LOI**	**Colorimetric Test**	**Liquid Limit Ratio**	**Classification**
	%	**%**	**%**	**%**	**Color No.**	**-**	**%**
Soil 1	49.0	27.2	21.8	3.2	1	0.96	Mineral soil*
Soil 4	46.7	35.0	11.6	5.2	3	0.88	Mineral soil*
Soil 5	32.1	20.1	12.0	1.2	1+	0.98	Mineral soil*
Soil 7	47.7	38.6	9.1	10.9	5	0.68	Mineral soil* with organic matter
Soil 9	34.0	14.7	19.3	4.5	4	1.00	Mineral soil*
Soil 11	151.1	123.0	28.1	43.2	-	0.58	Peat

* “Mineral soils” designated through USCS/AASHTO terminology (e.g. A-5)

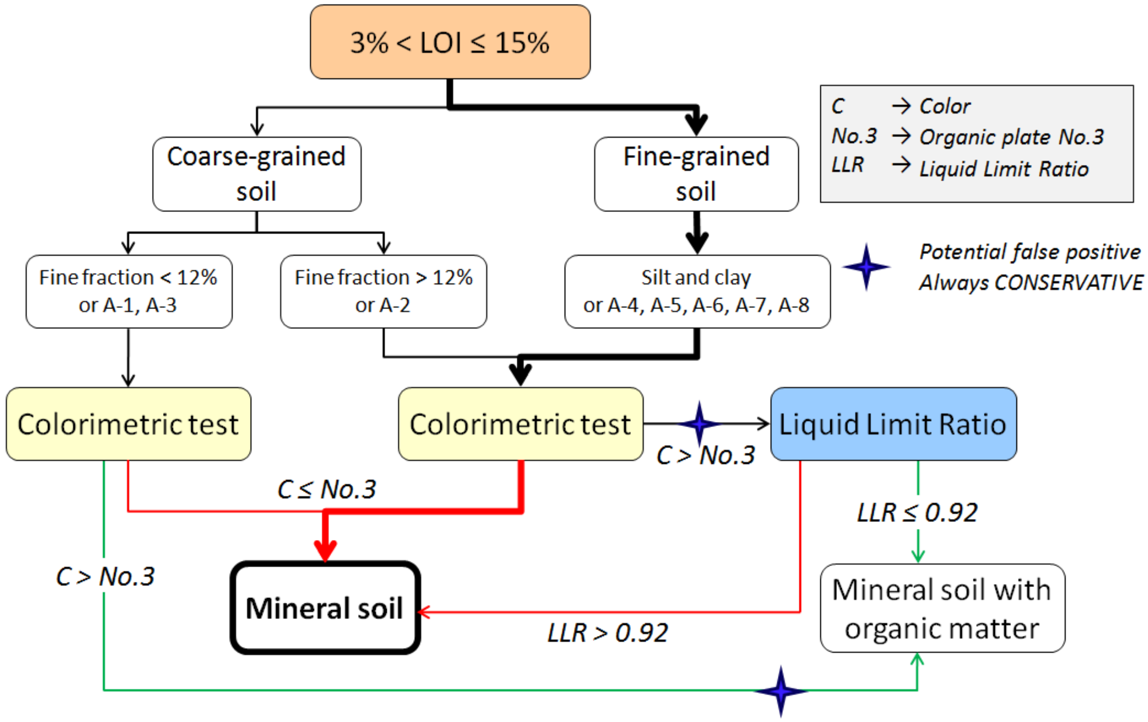

Figure 1-6: Supporting classification example - Soil 1

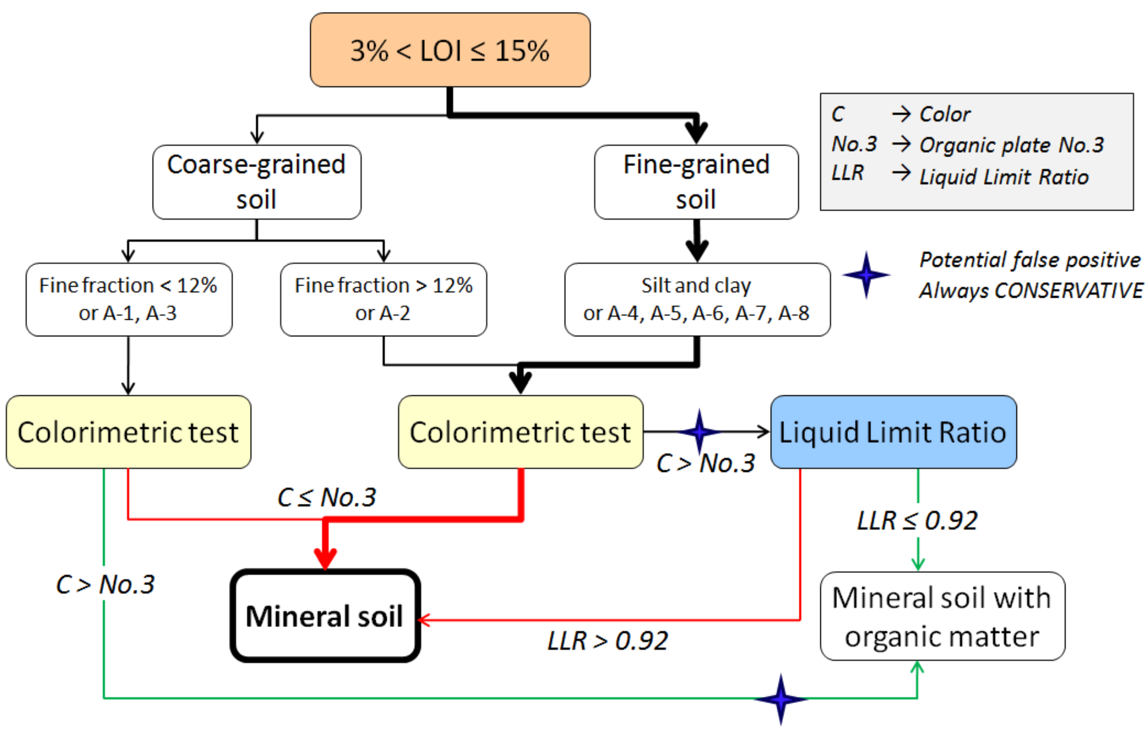

Figure 1-7: Supporting classification example - Soil 4

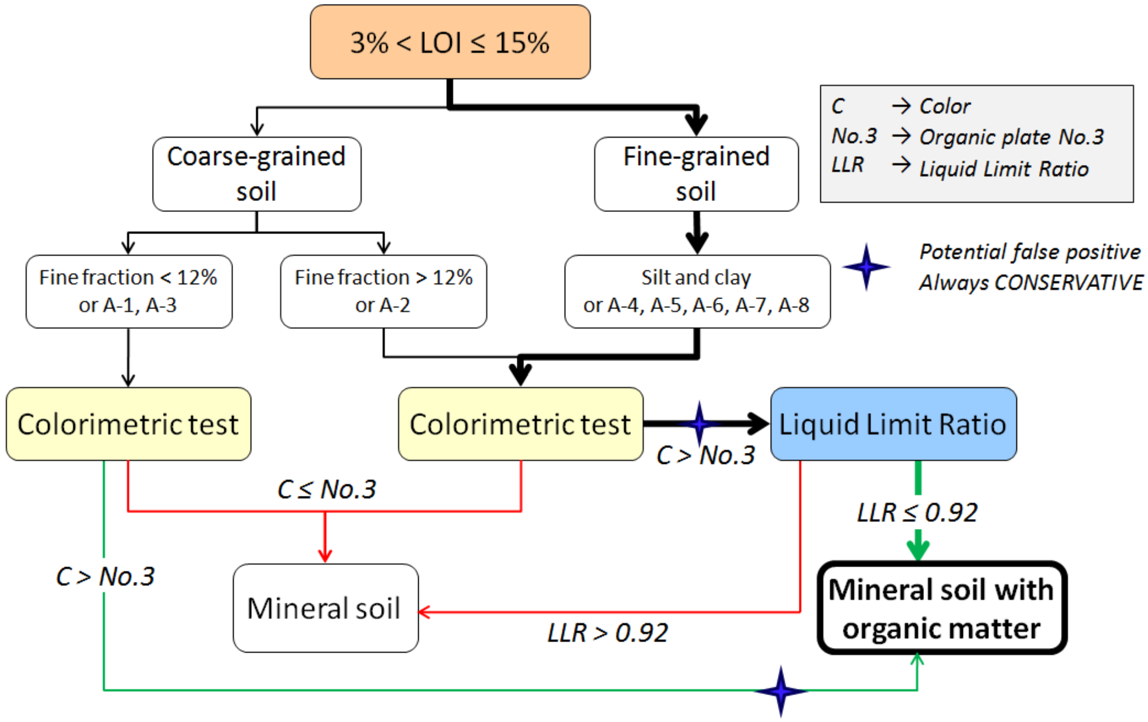

Figure 1-8: Supporting classification example - Soil 7

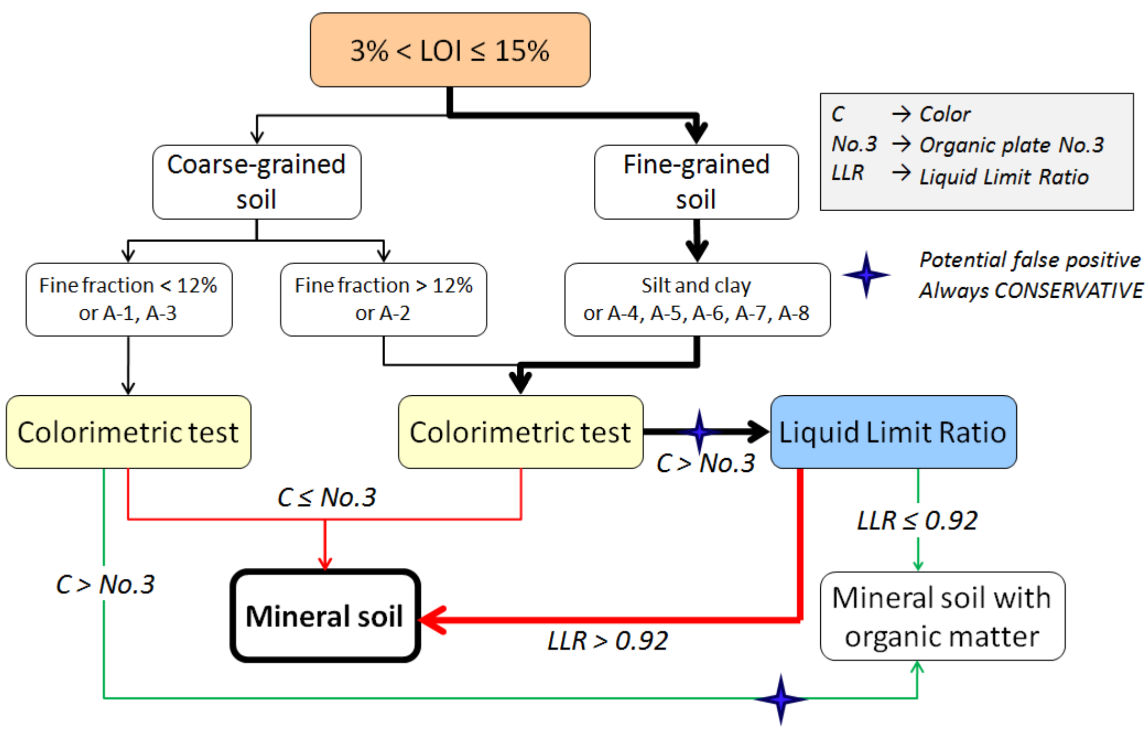

Figure 1-9: Supporting classification example - Soil 9

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CHAPTER 2. IDENTIFICATION AND CLASSIFICATION OF MARLY SOILS

2.1. Background

2.1.1. Importance of identifying marly soils

Marl soil deposits are encountered in the Midwest of the US, including the states of Indiana, Illinois, Michigan, and Ohio *(1, 2, 3, and 4)*. The term marl has been used in the regional area to designate carbonate-rich, light gray to almost white silts and clays formed by precipitation of calcite at the bottom of lakes or swamps *(1, 2, and 3)*. Marl soils sometimes contain noticeable amounts of fine sand *(3)*. Marl deposits are encountered often below highly organic soil or peat deposits *(1)* and contain shell fragments *(3)*. Marls are classified as an organic soil in accordance with the Ohio DOT soil classification system *(4)*. According to the Indiana DOT soil classification system, a soil with a calcium carbonate content of 26% to 40% is classified as marly soil while a soil with a calcium carbonate content larger than 40% is classified as marl *(2)*. One of the tests that the Indiana DOT uses to determine the calcium carbonate content in a soil is the chemical test, following ASTM C25. Both marly soils and marls fall into the ASSHTO soil class A-8 *(2)*. Marl soils typically have low dry density, very high moisture content and low shear strength. This makes them “problem soils” and unsuitable for pavement subgrade, may be prone to slope instability and have low bearing capacity.

2.1.2. Effect of $CaCO_3$ on geotechnical properties of soils

The carbonate content of a soil affects its geotechnical engineering properties. It affects index properties *(5, 6)*, the residual frictional angle of the soil *(7)*, the general stress-strain response *(8, 9, 10, and 11)*, and clay expansivity *(12)*. This section summarizes the effect of $CaCO_3$ on some of these properties:

1. Atterberg limits: In general both liquid limit and plastic limit decrease with carbonate content. In other words, as the carbonate content increases, marl soils tend to show less plastic behavior.
2. pH: As the $CaCO_3$ content of the soil increases, the pH tends to increase.
3. Color: As the percentage of calcium carbonate in the soil increases, the color of the soil changes from brown to light-gray, almost white.
4. Cohesion: With increasing carbonate content, the cohesion of the soil decreases.
5. Permeability: the permeability of a soil increases with the calcium carbonate content.

In summary, with increasing carbonate content, the LL, PL, PI, and activity of the soil decrease, the pH, permeability and friction angle increase while cohesion decreases. This trend however is applicable only for soils with no organic content. As discussed in section 1.1.2, the presence of organic matter strongly affects the soil properties and in some cases shows the opposite trend (e.g. Atterberg limits). Therefore, it can be concluded that the soil indices depend, to a large extent, on the $CaCO_3$ content when the soil does not contain any organic matter, but this trend becomes much weaker when the soil contains organic matter because the organic matter also significantly affects the soil indices. As a result, the geotechnical characteristics of marl soils depend on both organic content and $CaCO_3$ content.

2.2. New Classification System

Marl soils are usually categorized using classifications systems developed for clays and silts such as USCS (Unified Soil Classification System) and AASHTO. However, it may not be always appropriate to classify marl soils based only on their particle size distribution and consistency *(7)*. The index properties of marls depend on the carbonate content and on the type and content of minerals in the clay *(5)*. The research conducted as part of SPR-3227 re-endorsed the classification previously used by INDOT *(2)* that classifies soils into five groups based on the % of $CaCO_3$. Table 2-1 summarizes the five different categories for classification: soil with trace of marl, soil with little marl, soil with some marl, marly soil, and marl. It is recommended to use the "sequential" LOI for the determination of $CaCO_3$ *(13)*. Note that this classification system is applicable only to fine-grained soils.

Table 2-1: Criteria of marly soils classification *(13)*

Classification	**Calcium Carbonate Content (%)**
Soil* with trace of marl	1% < $CaCO_3$ < 9%
Soil* with little marl	10% < $CaCO_3$ < 17%
Soil* with some marl	18% < $CaCO_3$ < 25%
Marly soil*	26% < $CaCO_3$ < 40%
Marl	$CaCO_3$ > 40%

* "soil" designated through USCS/AASHTO terminology

2.2.1. Motivation

The initiative for the work conducted as part of SPR-3227 came from the need of INDOT to have a workable classification system and accurate and yet economical laboratory tests to determine the percentage of calcium carbonate in soils. INDOT performs chemical tests in accordance with ASTM C25 to determine the calcium carbonate content in a soil. The chemical test is not easy to perform; as a result, it is not routinely performed by most geotechnical engineering companies in Indiana. It is important however to determine the $CaCO_3$ content in a soil since this is a parameter that may be needed to decide if the soil can be accepted for construction.

An experimental investigation was carried out by Jung et al. *(13)* to propose a simple, practical method, to identify and classify marl soils in the laboratory. The percentage of calcium carbonate ($CaCO_3$) of the soil was determined with three different methods: 1) TGA (Thermo-Gravimetric Analysis); 2) "sequential" LOI (Loss on Ignition); and 3) chemical reaction following ASTM C25. The authors validated the use of any of these three methods (with the sequential LOI having the advantage that both organic and calcium carbonate content of the soil can be determined using a conventional furnace).

2.2.2. Classification system and screening approach

Laboratory:

The geotechnical engineering properties of marl soils depend on organic content and $CaCO_3$ content; therefore the soils should be classified in terms of both these parameters. Figure 2-1 summarizes the soil classification in terms of organic and calcium carbonate content in form of a flow chart based on the sequential LOI. In terms of organics, the soil is classified based on the organic classification system and the methods presented in section 1.2, whereas for calcium carbonate, the soil is classified based on classification system summarized in Table 2-1. Note that if the soil falls under the "mineral" category based on organic content, it is classified based on $CaCO_3$ content only. Otherwise, a dual classification is used (i.e. marly soil and mineral soil with organic matter).

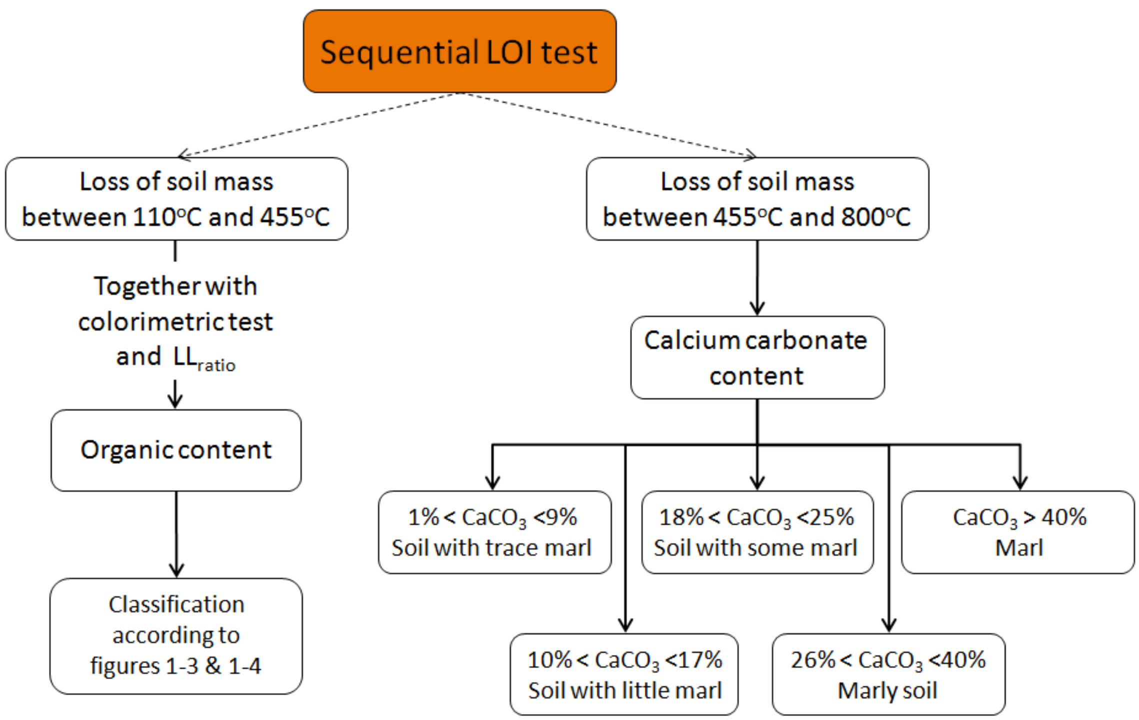

Figure 2-1: Approach for classifying soils in terms of calcium carbonate content based on sequential LOI test *(13)*

<u>Field</u>:

The color of the soil and its reaction with a 1M HCl solution may be used for a simple field classification. If a soil has a light gray color when dry, the soil can be potentially classified as marly soil or marl. If the soil has a different color, then the $CaCO_3$ content of the soil might be less than 20%.

The color determination must be complemented by a chemical test where a few drops of a 1M HCl solution are mixed with the soil. If effervescence is observed, this is an indication that the soil has a $CaCO_3$ content of at least 20%. The soil then can be classified as marl soil or marl. If no reaction is detected, the calcium carbonate content in the soil is smaller than 20%. A more precise determination of the $CaCO_3$ content, if needed, can be achieved by the sequential LOI test in the laboratory. Figure 2-2 is a schematic of the recommended field classification process using HCl reaction with the soil.

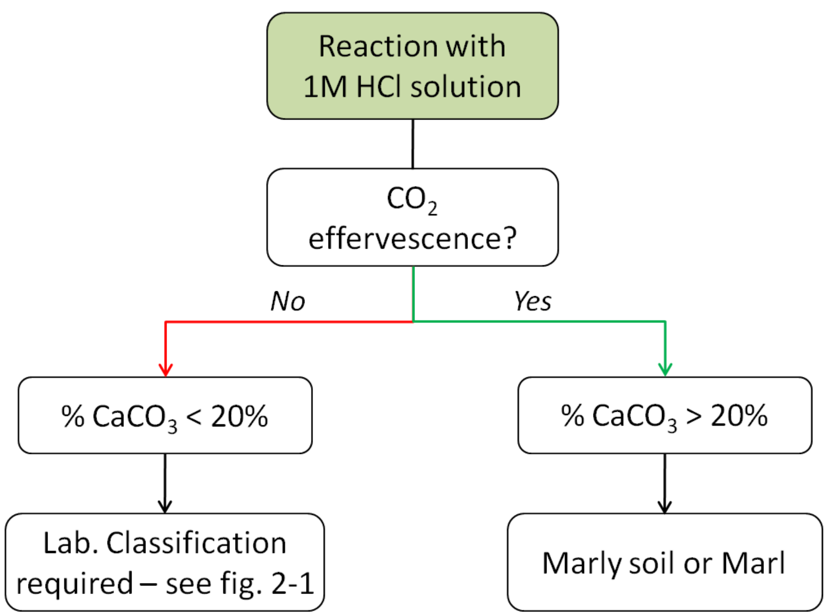

Figure 2-2: Recommended field classification procedure for marly soils *(13)*

2.3. Appendices

2.3.1. Procedures

2.3.1.1. "Sequential" loss on ignition Test (LOI)

a. References

1. Standard test methods for moisture, ash, and organic matter of peat and other organic soils (ASTM D2974 – 07a) *(14)*
2. Standard method of test for determination of organic content in soils by loss on ignition (AASHTO T267 – 86) *(15)*
3. Geotechnical Laboratory Measurements for Engineers (Germaine & Germaine, 2009) *(16)*
4. Determination of calcium carbonate content in soils using sequential loss on ignition test (ITM 507) *(17)*
5. Classification of marl soils *(13)*

b. Scope and Summary

This test method covers the procedure to determine the percentage of calcium carbonate (%$CaCO_3$) in soils using sequential LOI test *(17)*. The measurement is based on the fact that calcium carbonate decomposes into calcium oxide (CaO) and carbon dioxide (CO_2) in the range of 650°C to 800°C. The reduction in mass due to the release of CO_2 can be used to infer the calcium carbonate content.

c. Background

The loss on ignition (LOI) test can be used to determine the organic content and calcium carbonate content in the soil. In geotechnical engineering LOI tests have been used to measure organic content, heating the soil up to 455 °C, in accordance with AASHTO T267 – 86. Jung et al. *(13)* extended the LOI test in an attempt to determine the calcium carbonate content in the soil, and as a simpler alternative to the chemical tests (discussed later).

d. Apparatus

1. Oven capable of maintaining a constant temperature of 110°C ± 5°C.
2. Muffle furnace capable of attaining and maintaining a constant temperature of 800°C ± 10°C.
3. Scale of 0.01g readability.
4. Porcelain crucibles that can be heated up to 800°C.
5. Desiccator.
6. US standard sieve No. 10 (2 mm).

e. Procedure

1. Determine the mass of the porcelain crucible (M_c) to the nearest 0.01g. Note that each crucible should be washed, marked with a permanent paint and heated at the test temperature before it is used to perform any testing.
2. Obtain a representative soil specimen of 10g to 15g and sieve it through the No. 10 sieve (2 mm) *(15)*.
3. Place the soil sample in the crucible and determine the mass (M_{cws}) to the nearest 0.01g.
4. Oven-dry the specimen at 110°C ± 5°C for 24 hours (or until no mass loss is observed).
5. Remove the crucible and contents from the oven and place it in a desiccator to cool (~10 minutes).
6. Determine the dry mass ($M_{110°C}$) to the nearest 0.01g.
7. Place the crucible and contents in a muffle furnace at 455°C for 6 hours.
8. Remove the crucible from the furnace and place it in a desiccator to cool (~25 minutes).

9. Determine the mass of the crucible with the ash ($M_{455°C}$) to the nearest 0.01g.
10. Place the crucible and the soil into the furnace for 6 additional hours at a temperature of 800°C.
11. Remove the crucible from the furnace and place it in a desiccator to cool (~25 minutes).
12. Determine the mass of the crucible with the burnt soil ($M_{800°C}$) to the nearest 0.01g.

f. Calculation

The loss on ignition is computed as follows: (Refer to CHAPTER 1 for classification of organic soils)

$$LOI = \frac{M_{110°C} - M_{455°C}}{M_{110°C} - M_c} \times 100$$

The $CaCO_3$ content is computed as follows:

$$CaCO_3 = \frac{100}{44} \times \frac{M_{455°C} - M_{800°C}}{M_{110°C} - M_c} \times 100$$

Where:

LOI = loss on ignition of soil (%)

$M_{110°C}$ = mass of crucible and soil at 110°C (g)

$M_{455°C}$ = mass of crucible and ash at 455°C (g)

$M_{800°C}$ = mass of crucible and burnt soil at 800°C (g)

M_c = mass of crucible (g)

g. Report

Report the organic content and the percentage of calcium carbonate to the nearest 0.1% together with the temperatures of the muffle furnace. If more than one specimen is tested report the averages and the standard deviation.

Classify the soil based on both OC and $CaCO_3$ contents. If the soil falls under mineral" category based on organic content, it is classified based on $CaCO_3$ content only. Otherwise, dual classification shall be used (i.e. Marly soil and mineral soil with organic matter).

SEQUENTIAL LOSS ON IGNITION (LOI) – Sample Sheet

Soil Sample: Soil II
Location: I69-sec3 Seg13
Boring No: 3-37-TB-1
Sample No:
Sample Depth: 24 to 26ft (Bottom)

Date: Sat 9/17/2011
Time: 11:45am
Tested by: AH
Description: Dark Gray – Clayey
455 (6hrs) 800(6hrs)

Test No.	1	2			
Crucible No.	CE1	2			
$Mass_{crucible\ empty}$ M_c (g)	19.82	17.71			
$Mass_{crucible\ +\ wet\ soil}$ M_{cws} (g)	35.53	33.23			
$Mass_{crucible\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	30.03	27.80			
$Mass_{crucible\ +\ Ash\ (@\ 455°C)}$ $M_{455°C}$ (g)	29.81	27.58			
$Mass_{crucible\ +\ burnt\ soil\ (@\ 800°C)}$ $M_{800°C}$ (g)	27.24	25.08			
Loss on ignition LOI (%)	*2.1*	*2.2*			
$CaCO_3$ content (%)	*57.4*	*56.4*			

Average Loss on ignition (%) ____2.1_____
Average $CaCO_3$ content (%) ____56.9____

Observations: ______________________________

SEQUENTIAL LOSS ON IGNITION (LOI)

Soil Sample: ______________ Date: ______________
Location: ______________ Time: ______________
Boring No: ______________ Tested by: ______________
Sample No: ______________ Description: ______________________________
Sample Depth: ______________ ______________________________

Test No.	1	2	3	4	5
Crucible No.	A	B	C	D	F
Mass$_{\text{crucible empty}}$ M_c (g)					
Mass$_{\text{crucible + wet soil}}$ M_{cws} (g)					
Mass$_{\text{crucible + dry soil (@ 110°C)}}$ $M_{110°C}$ (g)					
Mass$_{\text{crucible + Ash (@ 455°C)}}$ $M_{455°C}$ (g)					
Mass$_{\text{crucible + burnt soil (@ 800°C)}}$ $M_{800°C}$ (g)					
Loss on ignition LOI (%)					
$CaCO_3$ content (%)					

Average Loss on ignition (%) ______________
Average $CaCO_3$ content (%) ______________

Observations: ____
____
____

2.3.1.2. HCl reaction test

According to Soil Taxonomy *(18)*, marl soils should react with dilute hydrochloric acid (HCl) to produce carbon dioxide (CO_2). Also, both standards, ASTM D4373 *(19)* and ASTM C25 *(20)*, use 1.0 M HCl solution to neutralize the calcium carbonate in the soil. As a consequence, 1.0 M HCl solution can be used to detect the calcium carbonate in the soil by observing the effervescence (bubbling effect) that occurs with the production of CO_2.

2.3.2. Indirect method for determination of $CaCO_3$ content

2.3.2.1. Chemical determination of $CaCO_3$ content

The chemical tests follow ASTM C25 *(20)*, which specifies a procedure to determine the neutralizing capacity of a calcareous material. About two grams of soil are placed into a 500-ml Erlenmeyer flask. 25 ml of 1.0 M hydrochloric acid (HCl) solution is added into the flask. About five minutes after the addition of the 1.0 M HCl solution the excess acid in the flask is titrated with 0.5 M sodium hydroxide (NaOH) solution using phenolphthalein as indicator. The volume of NaOH solution required for the titration of the excess acid is measured. The calcium carbonate content in the soil is:

$$\%\ CaCO_3 = \frac{5.0045(V_1N_1 - V_2N_2)}{W} \times 100$$

Where

V_1 = volume of the HCl solution used in ml

N_1 = normality of the HCl solution

V_2 = volume of the NaOH solution required for titration of excess acid in ml

N_2 = normality of the NaOH solution

W = weight of the soil sample in grams

Note that the value obtained with the above equation is not the percentage of calcium carbonate ($CaCO_3$), but the percentage of calcium carbonate equivalent (C.C.E.). This is so because other carbonate species such as magnesite and dolomite as well as calcite ($CaCO_3$) can react chemically with the 1M HCl solution. In other words, the chemical test describes the amount of all carbonate species in terms of C.C.E.

2.3.2.2. Thermogravimetric analysis (TGA)

a. *Basic principle*

Thermogravimetric analysis (TGA) is a thermal analysis technique used to quantify the weight loss of materials with increasing temperature. The standard testing procedure for this test is contained in ASTM E1131 *(21)*. A soil sample, typically 40mg in mass, is placed in a chamber, which, starting from room temperature, is heated to the desired temperature. The rate at which temperature is increased is typically 10-20°C/min, and pure Nitrogen is supplied at a rate of 50 ml/min. Different minerals decompose at well-defined temperatures. In the range of 650°C to 800°C, calcium carbonate ($CaCO_3$) decomposes into calcium oxide (CaO) and carbon dioxide (CO_2). As a consequence, the calcium carbonate content in a soil sample is determined from the weight loss of the soil between 650°C and 800°C as shown in the equation below:

$$\%CaCO_3 = \frac{100}{44} \times \frac{M_{650} - M_{800}}{M_{110}} \times 100$$

Where

M_{110} = mass of soil at 110°C (g)

M_{650} = mass of soil at 650°C (g)

M_{800} = mass of soil at 800°C (g)

b. *Interpretation of data*

Figure 2-3 shows an example of a TGA curve obtained from a test conducted by Jung et al. *(13)*, employing a heating rate of 10°C/min. It is observed that the weight of the soil sample has a sharp decrease in the range of temperatures between 650°C and

750°C. This is within the range where $CaCO_3$ decomposes into CaO and CO_2, and so the weight loss represents the $CaCO_3$ content. The figure also includes the derivative of the weight loss with respect to time, which shows a clear peak around 740°C.

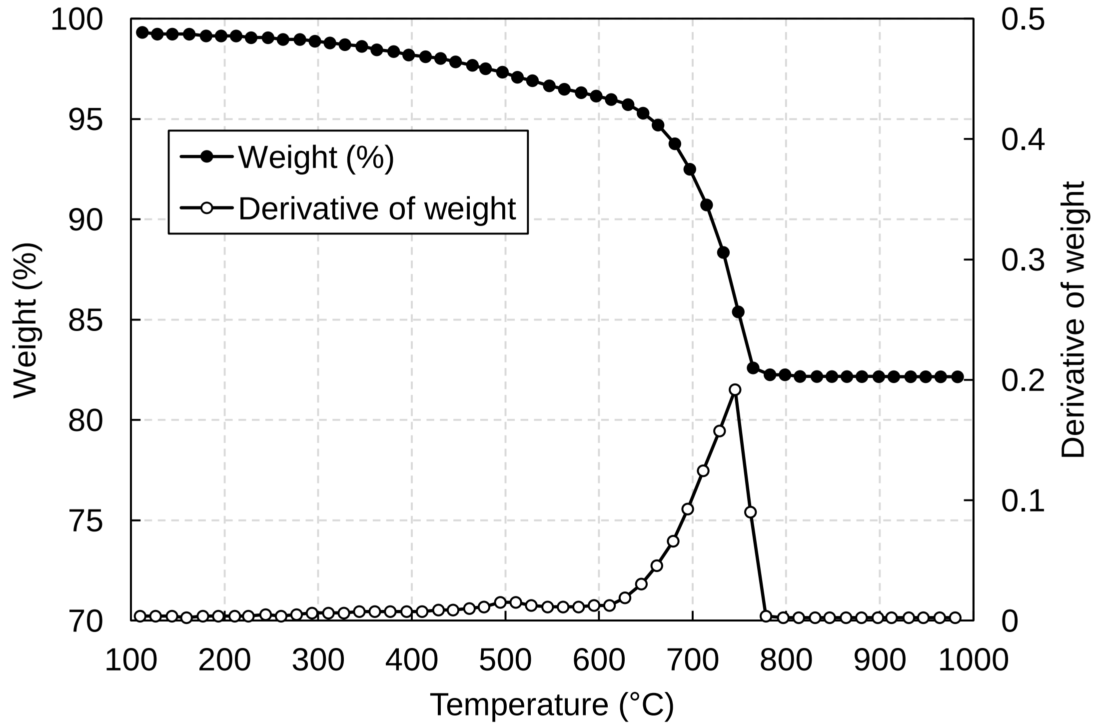

Figure 2-3: Weight loss obtained from TGA test (Jung et al., 2009)

2.3.3. Supporting classification examples

This section contains examples of the classification of marly soils containing $CaCO_3$ and organic matter based on the system and testing procedure proposed in Chapters 1 and 2. The table below summarizes the following: liquid limit, plasticity index, organic content (sequential LOI), Calcium carbonate content (sequential LOI), results of colorimetric test, liquid limit ratio, and the corresponding classification. Figure 2-4 to Figure 2-8 present the classification of five different soil samples based on the results of sequential LOI, colorimetric test and liquid limit ratio.

Table 2-2: Supporting classification examples for marly soils

Soil ID	LL	PI	O.C. (LOI)	$CaCO_3$ (LOI)	Colorimetric Test	Liquid Limit Ratio	Classification
	%	%	%	%	Color No.	-	%
Soil 1-1	41	15	2.5	47	-	-	Marl
Soil 1-9	32	17	1.5	33	-	-	Marly soil*
Soil 2-1	73	23	17.3	41	-	-	Marl & organic soil
Soil 3-2	60	21	6.2*	21	-	-	Soil* with some marl[+]
Soil 3-4	68	24	15.5	11	-	-	Organic soil with little marl

[+]Organic content is between 3% and 15%. Need to conduct colorimetric test and liquid limit ratio to have a full classification for organics.

* "soil" designated through USCS/AASHTO terminology

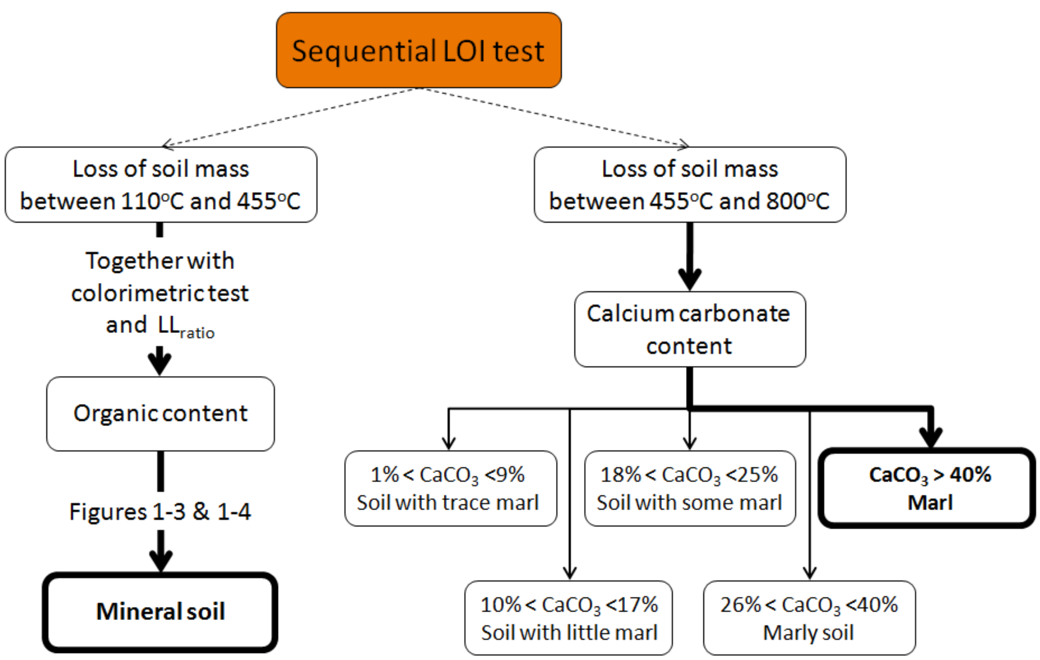

Figure 2-4: Supporting classification example - Soil 1-1

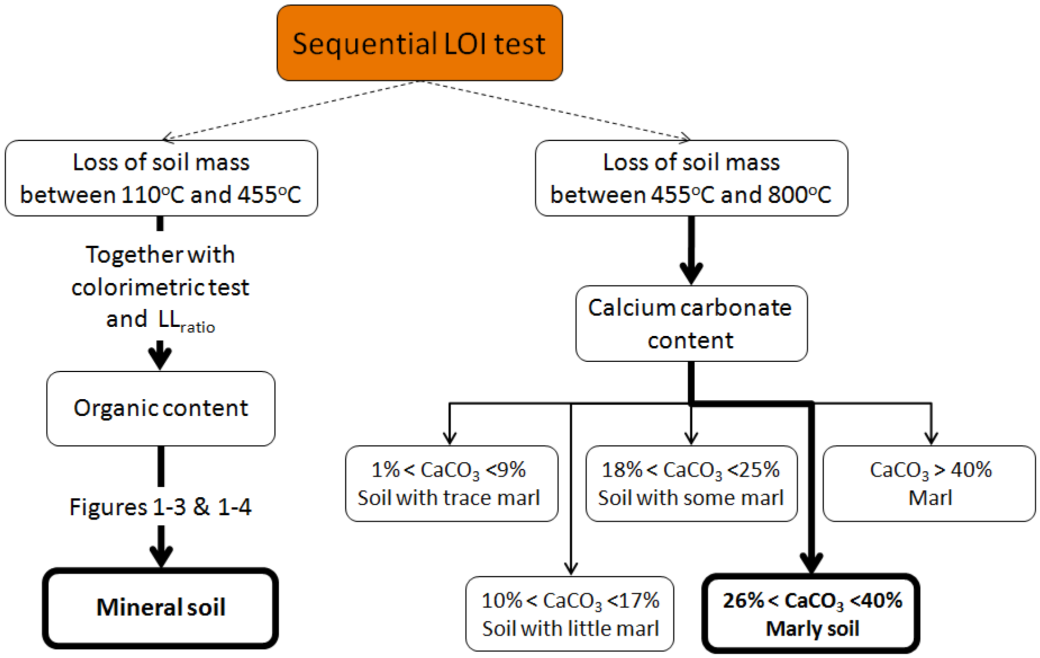

Figure 2-5: Supporting classification example - Soil 1-9

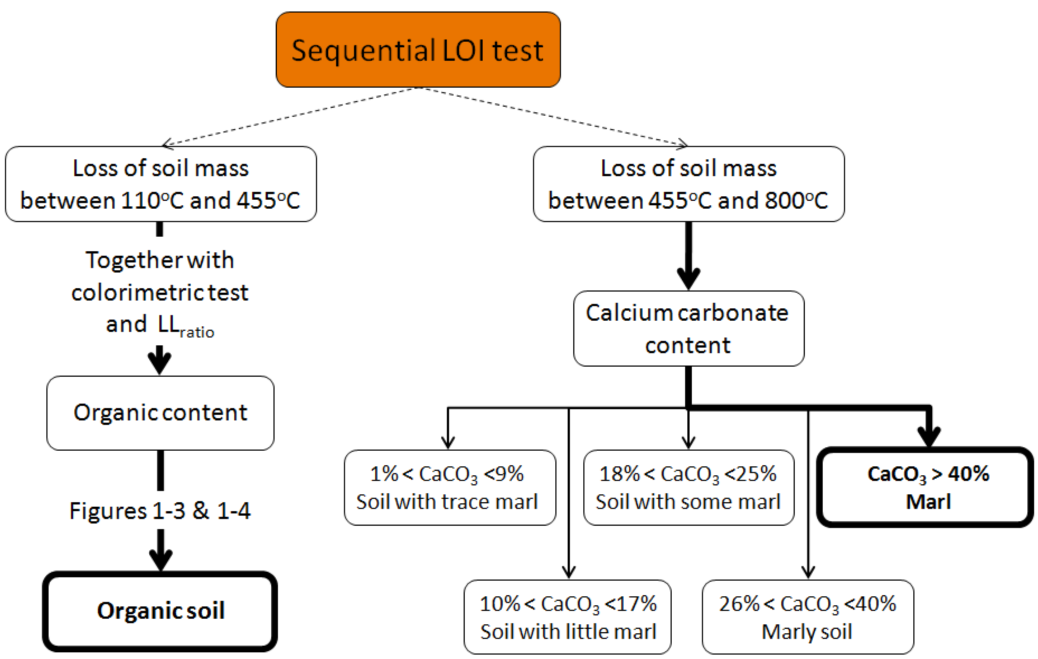

Figure 2-6: Supporting classification example - Soil 2-1

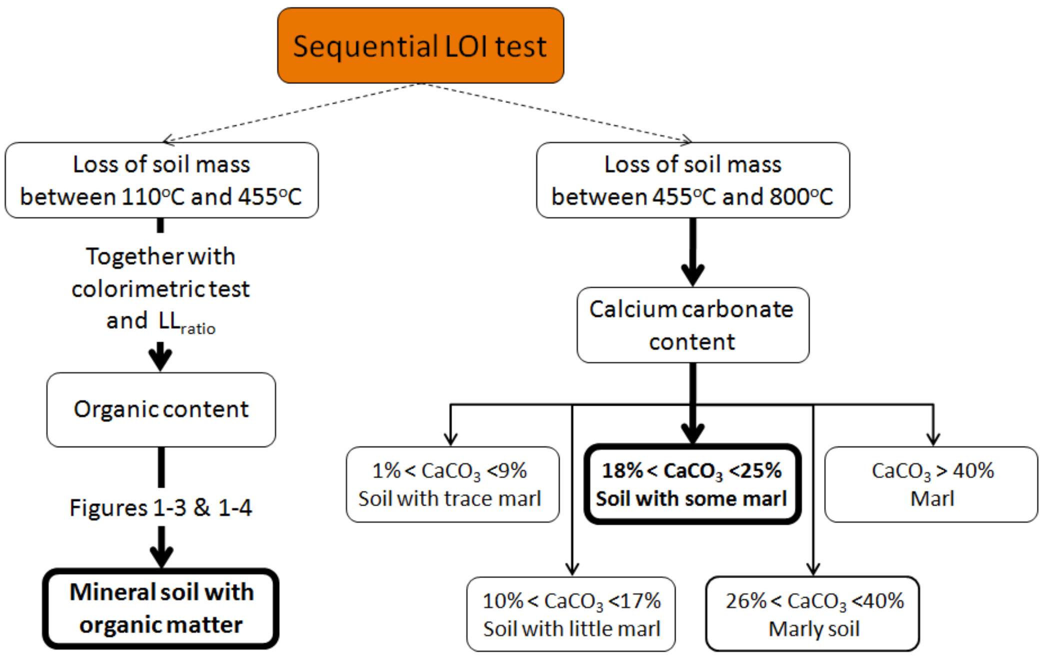

Figure 2-7: Supporting classification example - Soil 3-2

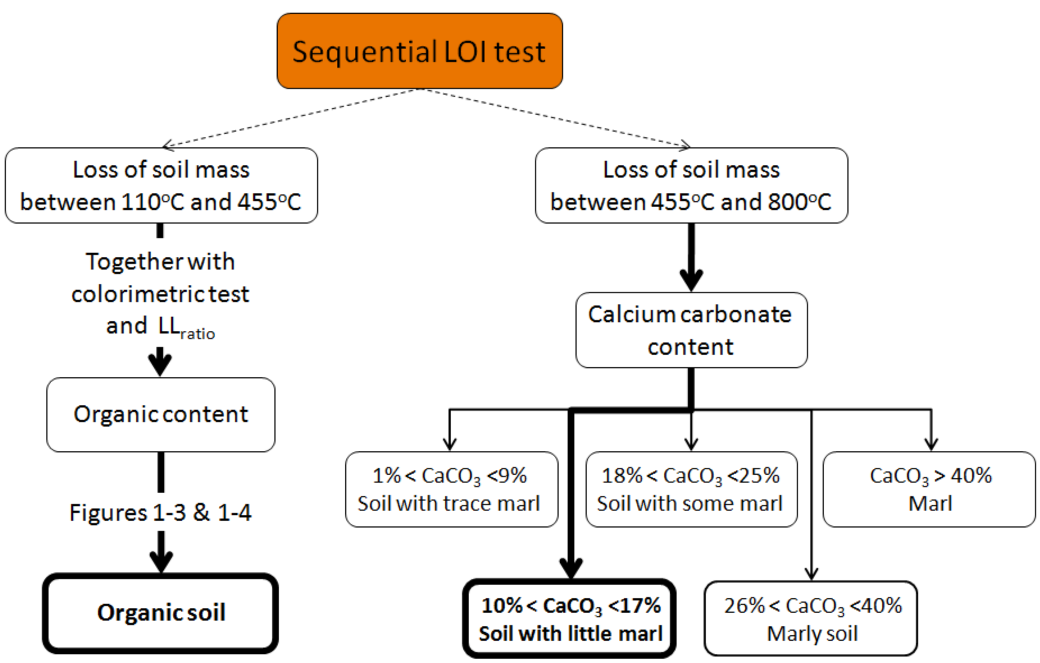

Figure 2-8: Supporting classification example - Soil 3-4

2.4. References

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APPENDIX 3

IDENTIFICATION AND CLASSIFICATION OF ORGANIC SOILS

STEP 1: LOSS ON IGNITION TEST (LOI)

I- REFERENCES

1. ASTM D2974 – 07a
2. AASHTO T267 – 86
3. Geotechnical Laboratory Measurements for Engineers (Germaine & Germaine, 2009)

II- SCOPE AND SUMMARY

This test method describes the process to determine the organic content using the Loss on Ignition test (LOI) and is based on finding the reduction in mass of an oven-dried specimen subjected to elevated temperature such that organic matter is burnt off.

III- APPARATUS

1. Oven capable of maintaining a constant temperature of 110°C ± 5°C.
2. Muffle furnace capable of attaining and maintaining a constant temperature of 455°C ± 10°C.
3. Scale of 0.01g readability.
4. Porcelain crucibles that can be heated up to 455°C.
5. Desiccator.
6. US standard sieve No. 10 (2 mm).

IV- PROCEDURE

1. Determine the mass of the porcelain crucible (M_C) to the nearest 0.01g. Note that each crucible should be washed, marked with a permanent paint and heated at the test temperature before it is used to perform any testing.
2. Obtain a representative soil specimen of 10g to 15g, and sieve it through the No. 10 sieve (2 mm).

3. Place the soil sample in the crucible and determine the mass (M_{cws}) to the nearest 0.01g.
4. Oven-dry the specimen at 110°C ± 5°C for 24 hours (or until no mass loss is observed).
5. Remove the crucible and its content from the oven and place it in a desiccator to cool (~10 minutes).
6. Determine the dry mass ($M_{110°C}$) to the nearest 0.01g.
7. Place the crucible and contents in a muffle furnace at 455°C for 6 hours.
8. Remove the crucible from the furnace and place it in a desiccator to cool (~25 minutes).
9. Determine the final mass ($M_{455°C}$) to the nearest 0.01g.

V- CALCULATION

The loss on ignition can be computed as follows:

$$\text{LOI} = \frac{M_{110^\circ C} - M_{455^\circ C}}{M_{110^\circ C} - M_c} \times 100$$

Where:

LOI = loss on ignition of soil (%)

$M_{110°C}$ = mass of crucible and soil at 110°C (g)

$M_{455°C}$ = mass of crucible and ash at 455°C (g)

M_c = mass of crucible (g)

VI- REPORT

Report the loss on ignition to the nearest 0.1% together with the temperature of the muffle furnace. If more than one specimen is tested report the average and the standard deviation.

LOSS ON IGNITION (LOI) – Sample Sheet

Soil Sample:	Soil I	Date:	Sat 10/22/2011
Location:	I69-Sec3 Seg13	Time:	11:00am
Boring No:	3-31-TB-2A	Tested by:	AH
Sample No:		Description:	Black - silty
Sample Depth:	30 to 32ft (Bottom)		455 (6hrs) 800(6hrs)

Test No.	1	2	3	4	5
Crucible No.	A	B	C	D	F
$Mass_{crucible\ empty}$ M_c (g)	17.67	17.94			
$Mass_{crucible\ +\ wet\ soil}$ M_{cws} (g)	34.29	32.80			
$Mass_{crucible\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	30.02	28.44			
$Mass_{crucible\ +\ Ash\ (@\ 455°C)}$ $M_{455°C}$ (g)	29.20	27.47			
Loss on Ignition LOI (%)	*6.6*	*9.3*			

Average Loss on Ignition LOI (%) ____8.0_____

Observations: ____

____

____

APPENDIX 3

STEP 2: COLORIMETRIC TEST

I- REFERENCES

1. ASTM C40 – 04
2. ASTM D1544 – 04
3. AASHTO T21 – 05
4. AASHTO M147 – 65

II- SCOPE AND SUMMARY

This test covers the procedure for a colorimetric test that detects the presence of organic impurities in fine aggregates for concrete. The test method consists of mixing the soil specimen with a sodium hydroxide solution and observing the color produced. If it is darker than a standard color (Gardner Color Standard No. 11), organic impurities may be present.

III- APPARATUS

1. Transparent graduated glass bottles with a minimum capacity of 250 ml.
2. A 3% sodium hydroxide solution NaOH (dissolve 3g of NaOH in 97g of water)
3. Glass color standard (Gardner color Standard No. 11).
4. US standard sieve No. 10 (2 mm).

IV- PROCEDURE

1. Air-dry the entire soil sample in a pan and, when necessary, crush it so that it passes the No.10 sieve (2 mm).
2. Fill the glass bottle to the 130 ml level with the soil sample to be tested.
3. Add the sodium hydroxide solution until the volume reaches the 200 ml level.
4. Close the bottle with a stopper and vigorously shake for a couple of minutes, and then let it stand for 24 hours.
5. At the end of the 24-hour standing period, hold the bottle with the test sample and the Gardner Color Standard No.11 side-by-side, and compare the color

of the supernatant liquid above the sample with the organic plate No. 1 to 5 (Gardner Color Standard No.11).

V- REPORT

Report the organic plate number which is closest to the color of the supernatant. The color depends on the presence of organic matter. Specifically, according to the standard, “if the color of the supernatant liquid is darker than that of the standard color of solution or the glass color standard organic plate No. 3 (Gardner Color Standard No.11), the fine aggregate under test shall be considered to possibly contain injurious organic impurities”.

APPENDIX 3

STEP 3: LIQUID LIMIT RATIO DETERMINATION

I- REFERENCES

1. ASTM D4318 – 10
2. ASTM D2487 – 11
3. AASHTO T89 – 10
4. Geotechnical Laboratory Measurements for Engineers (Germaine & Germaine, 2009)

II- SCOPE AND SUMMARY

The method uses the liquid limit test to obtain a qualitative measure of the organic matter content of a soil. The procedure is based on the comparison of the liquid limit of a sample before and after oven-drying (also known as liquid limit ratio).

III- APPARATUS

1. Oven capable of maintaining a constant temperature of 110°C ± 5°C.
2. Casagrande liquid limit device.
3. Flat grooving tool.
4. Scale of 0.01g readability.
5. Aluminum tares for water content determination.
6. Desiccator.
7. Mixing bowl.
8. US standard sieve No. 40 (425 μm).

IV- PROCEDURE

1. Adjust the height of drop for the Casagrande liquid limit device to 10mm ± 0.2mm (vertical distance between the base and the point on the cup that comes in contact with the base).
2. Check the resilience rebound of the apparatus base by dropping a 7.94mm (5/16 in) diameter steel ball on the base from a height of 254mm (10 in). The

ratio of the rebound height to the drop height should be between 77% and 90%.

3. Sieve soil through US No. 40 sieve and obtain natural water content (never oven dry soil prior to tests).
4. Mix about 100 g of soil with distilled water to about 15 drop consistency, cover to prevent loss of moisture and place it in a humid room for 24 hours to temper.
5. Place soil in the Casagrande cup to a maximum depth of ½ inch. The soil should form a flat horizontal surface with the bottom lip of the cup. Ensure that entrapped air is removed and that the flat surface is smooth.
6. Groove the soil with the flat grooving tool maintaining the tool perpendicular to the surface of the cup throughout its movement.
7. Lift and drop the cup by turning the crank at a rate of 2 blows/second until the groove closes for a length of 13 mm (½ inch) and record the number of blows.
8. Remove soil from cup and return to the dish. Wash and dry the cup and grooving tool and reattach the cup to the carriage in preparation for the next trial.
9. Mix soil in a dish and repeat steps 5, 6, 7 and 8 until two consistent blow counts (± 1) are measured.
10. Remove about 10 g of paste perpendicular and across the closed groove, place in a tare of known mass and put it in the oven (110°C ± 5°C) for water content measurements.
11. Obtain four separate water content determinations between 15 and 35 blows by drying the soil slightly and repeating steps 5 through 10.
12. Plot the water content against log of number of blows, draw the flow curve and select the liquid limit as the intersection of this curve and the 25 blow line.
13. Prepare another soil sample by working the material through the US No. 40 sieve and oven-dry it for 24 hours at 110°C ± 5°C (or until no mass loss is observed).
14. Repeat steps 4 through 12 and determine the oven-dried liquid limit.

V- CALCULATION

The liquid limit ratio can be computed as follows:

$$LL_{ratio} = \frac{LL_{\text{oven dried}}}{LL_{\text{not dried}}}$$

Where:

LL_{ratio} = Liquid limit ratio

$LL_{\text{oven dried}}$ = Liquid limit for oven-dried soil

$LL_{\text{not dried}}$ = Liquid limit for not oven-dried soil

VI- REPORT

Report the average liquid limits before and after oven-drying along with the standard deviation. Also, provide the liquid limit ratio and note whether the specimen is an organic or inorganic soil.

LIQUID LIMIT TEST (LL) – Sample Sheet

Soil Sample:	Soil I	Date:	Thu 10/27/2011
Location:	I69-Sec3 Seg13	Time:	11:30am
Boring No:	3-31-TB-2A	Tested by:	AH/MS
Sample No:		Description:	Black - silty
Sample Depth:	30 to 32ft (Bottom)		455 (6hrs) 800(6hrs)

Oven-dried: ☐ Yes ■ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
$Mass_{tare\ empty}$ M_t (g)	1.32	1.30	1.33	1.31
$Mass_{tare\ +\ wet\ soil}$ M_{tws} (g)	4.90	4.95	4.91	5.60
$Mass_{tare\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	3.57	3.63	3.62	4.07
Water content w (%)	*58.9*	*56.7*	*56.2*	*55.6*
Number of blows N	14	25	29	34

Liquid Limit = ____56.7%____

Observations: ______________________________

APPENDIX 3

LIQUID LIMIT TEST (LL) – Sample Sheet

Soil Sample:	Soil I	Date:	Thu 10/27/2011
Location:	I69-Sec3 Seg13	Time:	11:30am
Boring No:	3-31-TB-2A	Tested by:	AH/MS
Sample No:		Description:	Black - silty
Sample Depth:	30 to 32ft (Bottom)		455 (6hrs) 800(6hrs)

Oven-dried: ■ Yes ☐ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
Mass$_{\text{tare empty}}$ M_t (g)	1.30	1.34	1.30	1.33
Mass$_{\text{tare + wet soil}}$ M_{tws} (g)	5.34	4.89	6.48	6.05
Mass$_{\text{tare + dry soil (@ 110°C)}}$ $M_{110°C}$ (g)	4.03	3.77	4.86	4.59
Water content w (%)	*47.9*	*46.4*	*45.5*	*44.9*
Number of blows N	16	22	28	33

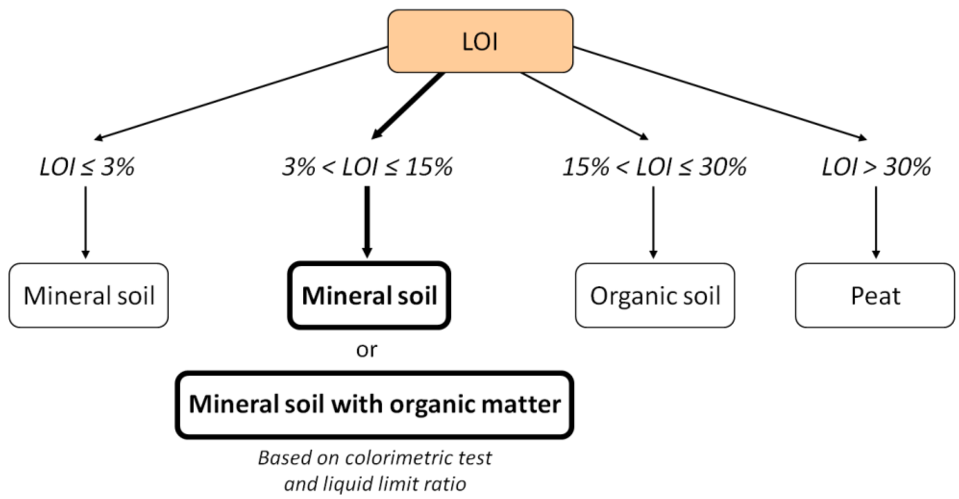
Liquid Limit = ____46.0%____

Observations: ____

APPENDIX 3

Supporting Classification example:

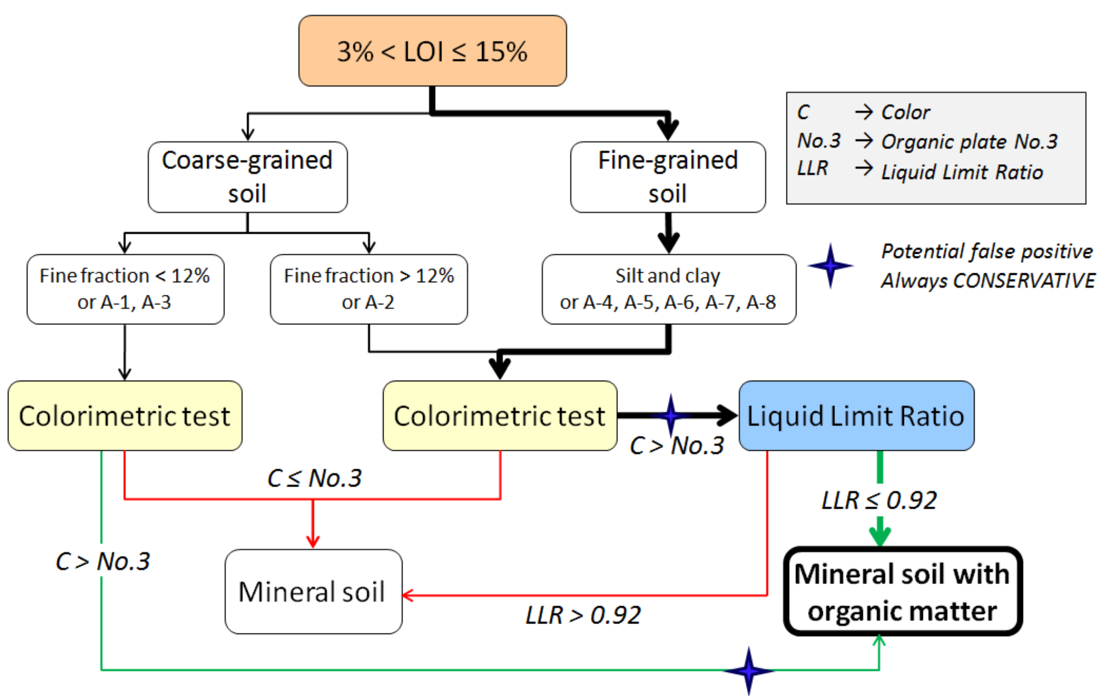
Step 1: LOI = 8.0 % (between 3% and 15%)



Fine-grained Soil (more than 35% passing sieve no. 200)

Step 2: Color = organic plate No. 5 (> No. 3)

Step 3: LLR = 0.81 (< 0.92)



Therefore Soil I is classified as *Mineral soil with organic matter.*

APPENDIX 3

LOSS ON IGNITION (LOI)

Soil Sample: ____________ Date: ____________

Location: ____________ Time: ____________

Boring No: ____________ Tested by: ____________

Sample No: ____________ Description: ____________________________

Sample Depth: ____________ ____________________________

Test No.	1	2	3	4	5
Crucible No.	A	B	C	D	F
$\text{Mass}_{\text{crucible empty}}$ M_c (g)					
$\text{Mass}_{\text{crucible + wet soil}}$ M_{cws} (g)					
$\text{Mass}_{\text{crucible + dry soil (@ 110°C)}}$ $M_{110°C}$ (g)					
$\text{Mass}_{\text{crucible + Ash (@ 455°C)}}$ $M_{455°C}$ (g)					
Loss on Ignition LOI (%)					

Average Loss on Ignition LOI (%) ____________

Observations: ____

____

____

LIQUID LIMIT TEST (LL)

Soil Sample: ____________
Location: ____________
Boring No: ____________
Sample No: ____________
Sample Depth: ____________

Date: ____________
Time: ____________
Tested by: ____________
Description: ______________________
____

Oven-dried: ☐ Yes ☐ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
$Mass_{tare\ empty}$ M_t (g)				
$Mass_{tare\ +\ wet\ soil}$ M_{tws} (g)				
$Mass_{tare\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)				
Water content w (%)				
Number of blows N				

Liquid Limit = ____________

Observations: ____
____
____

APPENDIX 4

IDENTIFICATION AND CLASSIFICATION OF MARLY SOILS

<u>"SEQUENTIAL" LOSS ON IGNITION TEST (LOI)</u>

I- REFERENCES

1. ASTM D2974 – 07a
2. AASHTO T267 – 86
3. Geotechnical Laboratory Measurements for Engineers (Germaine & Germaine, 2009)
4. Determination of calcium carbonate content in soils using sequential loss on ignition test (ITM 507)
5. Classification of marl soils (Jung et al., 2009)

II- SCOPE AND SUMMARY

This test method covers the procedure to determine the percentage of calcium carbonate (%$CaCO_3$) in soils using sequential LOI test.

III- APPARATUS

1. Oven capable of maintaining a constant temperature of 110°C ± 5°C.
2. Muffle furnace capable of attaining and maintaining a constant temperature of 800°C ± 10°C.
3. Scale of 0.01g readability.
4. Porcelain crucibles that can be heated up to 800°C.
5. Desiccator.
6. US standard sieve No. 10 (2 mm).

IV- PROCEDURE

1. Determine the mass of the porcelain crucible (M_c) to the nearest 0.01g. Note that each crucible should be washed, marked with a permanent paint and heated at the test temperature before it is used to perform any testing.

2. Obtain a representative soil specimen of 10g to 15g and sieve it through the No. 10 sieve (2 mm).
3. Place the soil sample in the crucible and determine the mass (M_{cws}) to the nearest 0.01g.
4. Oven-dry the specimen at 110°C ± 5°C for 24 hours (or until no mass loss is observed).
5. Remove the crucible and contents from the oven and place it in a desiccator to cool (~10 minutes).
6. Determine the dry mass ($M_{110°C}$) to the nearest 0.01g.
7. Place the crucible and contents in a muffle furnace at 455°C for 6 hours.
8. Remove the crucible from the furnace and place it in a desiccator to cool (~25 minutes).
9. Determine the mass of the crucible with the ash ($M_{455°C}$) to the nearest 0.01g.
10. Place the crucible and the soil into the furnace for 6 additional hours at a temperature of 800°C.
11. Remove the crucible from the furnace and place it in a desiccator to cool (~25 minutes).
12. Determine the mass of the crucible with the burnt soil ($M_{800°C}$) to the nearest 0.01g.

V- CALCULATION

The loss on ignition is computed as follows:

$$\text{LOI} = \frac{M_{110^\circ C} - M_{455^\circ C}}{M_{110^\circ C} - M_c} \text{ x } 100$$

The $CaCO_3$ content is computed as follows:

$$CaCO_3 = \frac{100}{44} \times \frac{M_{455^\circ C} - M_{800^\circ C}}{M_{110^\circ C} - M_c} \text{ x } 100$$

Where:

LOI = loss on ignition of soil (%)

$M_{110°C}$ = mass of crucible and soil at 110°C (g)

$M_{455°C}$ = mass of crucible and ash at 455°C (g)

$M_{800°C}$ = mass of crucible and burnt soil at 800°C (g)

M_c = mass of crucible (g)

VI- REPORT

Report the organic content and the percentage of calcium carbonate to the nearest 0.1% together with the temperatures of the muffle furnace. If more than one specimen is tested report the averages and the standard deviation.

Classify the soil based on both OC and $CaCO_3$ contents. If the soil falls under “mineral” category based on organic content, it is classified based on $CaCO_3$ content only. Otherwise, dual classification shall be used (i.e. Marly soil and mineral soil with organic matter).

APPENDIX 4

SEQUENTIAL LOSS ON IGNITION (LOI) – Sample Sheet

Soil Sample:	Soil II	Date:	Sat 9/17/2011
Location:	I69-sec3 Seg13	Time:	11:45am
Boring No:	3-37-TB-1	Tested by:	AH
Sample No:		Description:	Dark Gray – Clayey
Sample Depth:	24 to 26ft (Bottom)		455 (6hrs) 800(6hrs)

Test No.	1	2			
Crucible No.	CE1	2			
Mass$_{\text{crucible empty}}$ M_c (g)	19.82	17.71			
Mass$_{\text{crucible + wet soil}}$ M_{cws} (g)	35.53	33.23			
Mass$_{\text{crucible + dry soil (@ 110°C)}}$ $M_{110°C}$ (g)	30.03	27.80			
Mass$_{\text{crucible + Ash (@ 455°C)}}$ $M_{455°C}$ (g)	29.81	27.58			
Mass$_{\text{crucible + burnt soil (@ 800°C)}}$ $M_{800°C}$ (g)	27.24	25.08			
Loss on ignition LOI (%)	*2.1*	*2.2*			
$CaCO_3$ content (%)	*57.4*	*56.4*			

Average Loss on ignition (%) ____2.1_____

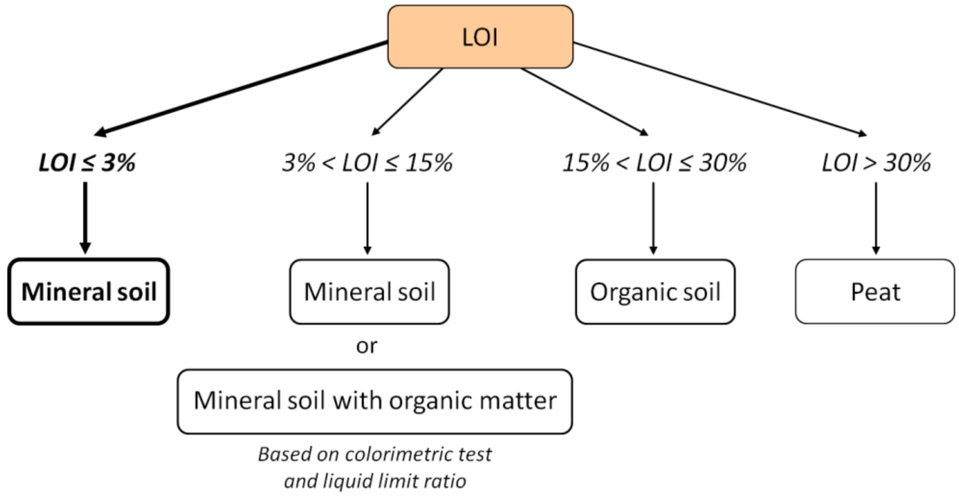
Average $CaCO_3$ content (%) ____56.9____

Observations: ______________________________

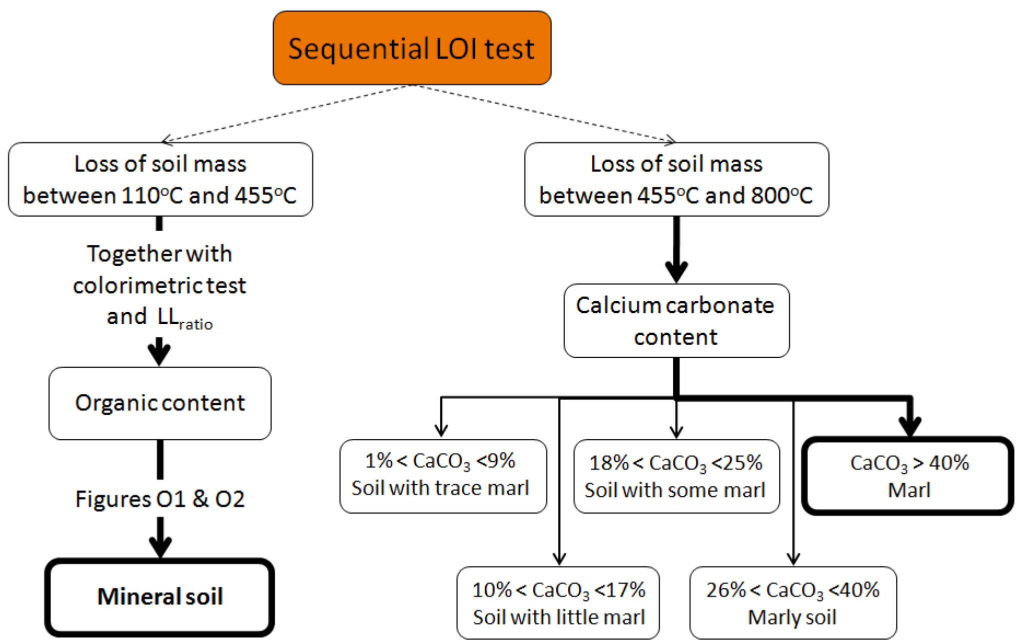
APPENDIX 4

Supporting Classification example:

Sequential LOI: %OC = 2.1% (< 3%)



Sequential LOI: %$CaCO_3$ = 56.9% (> 40%)



Therefore Soil II is classified as *Marl*

SEQUENTIAL LOSS ON IGNITION (LOI)

Soil Sample: ____________ Date: ____________
Location: ____________ Time: ____________
Boring No: ____________ Tested by: ____________
Sample No: ____________ Description: ________________________
Sample Depth: ____________ ________________________

Test No.	1	2	3	4	5
Crucible No.	A	B	C	D	F
$Mass_{crucible\ empty}$ M_c (g)					
$Mass_{crucible\ +\ wet\ soil}$ M_{cws} (g)					
$Mass_{crucible\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)					
$Mass_{crucible\ +\ Ash\ (@\ 455°C)}$ $M_{455°C}$ (g)					
$Mass_{crucible\ +\ burnt\ soil\ (@\ 800°C)}$ $M_{800°C}$ (g)					
Loss on ignition LOI (%)					
$CaCO_3$ content (%)					

Average Loss on ignition (%) ____________
Average $CaCO_3$ content (%) ____________

Observations: ____
____
____

APPENDIX 5

Organics

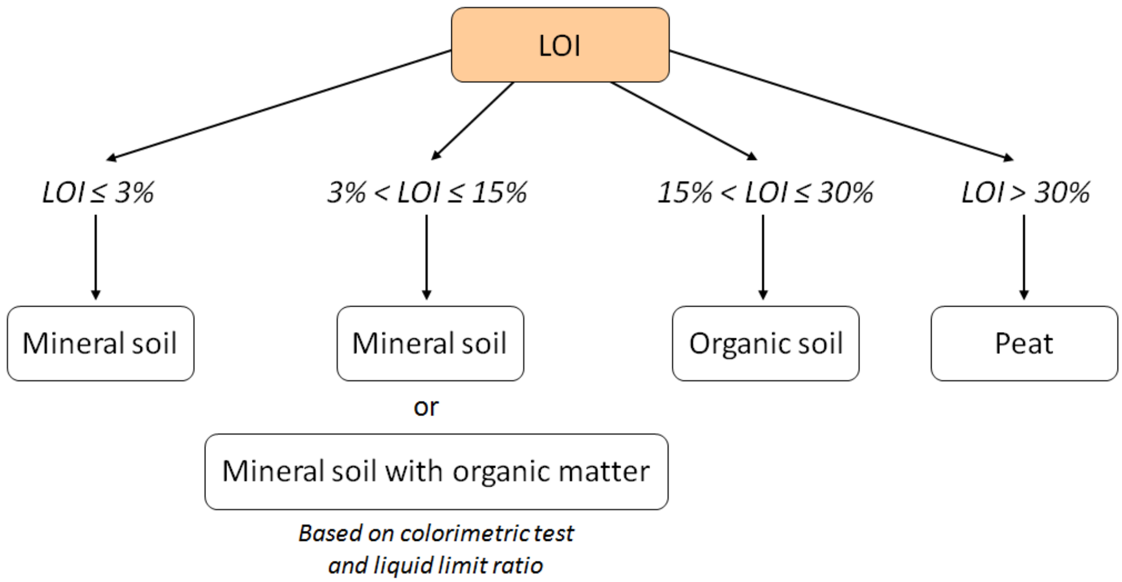


Figure O1

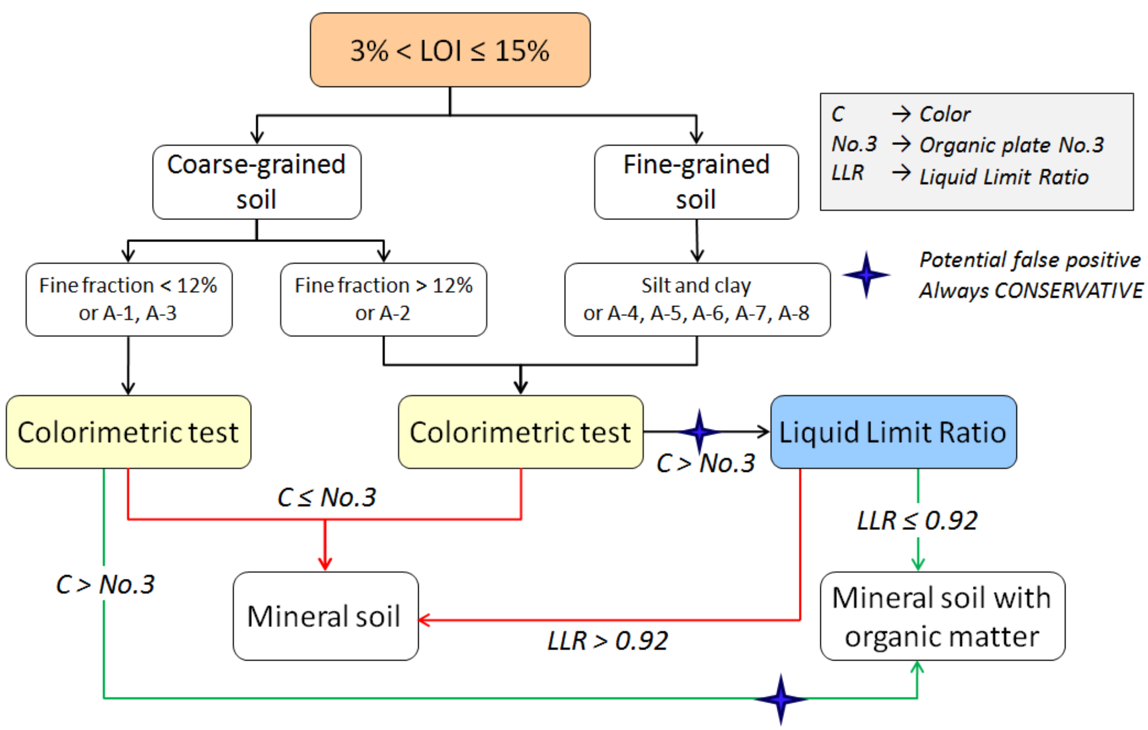
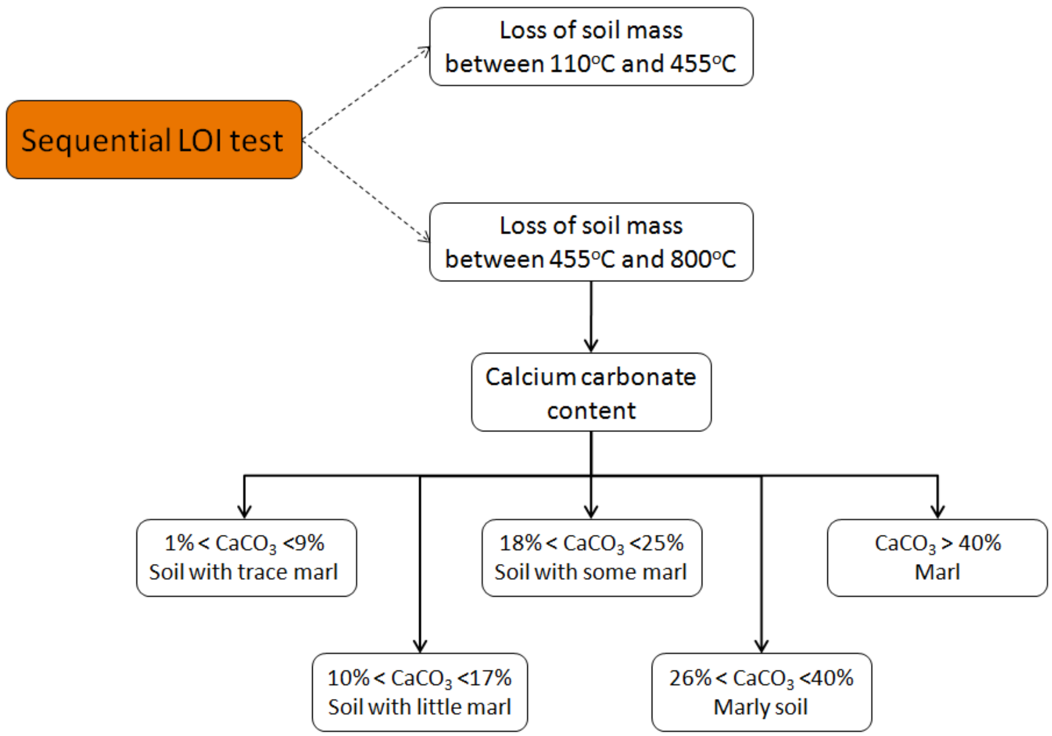


Figure O2

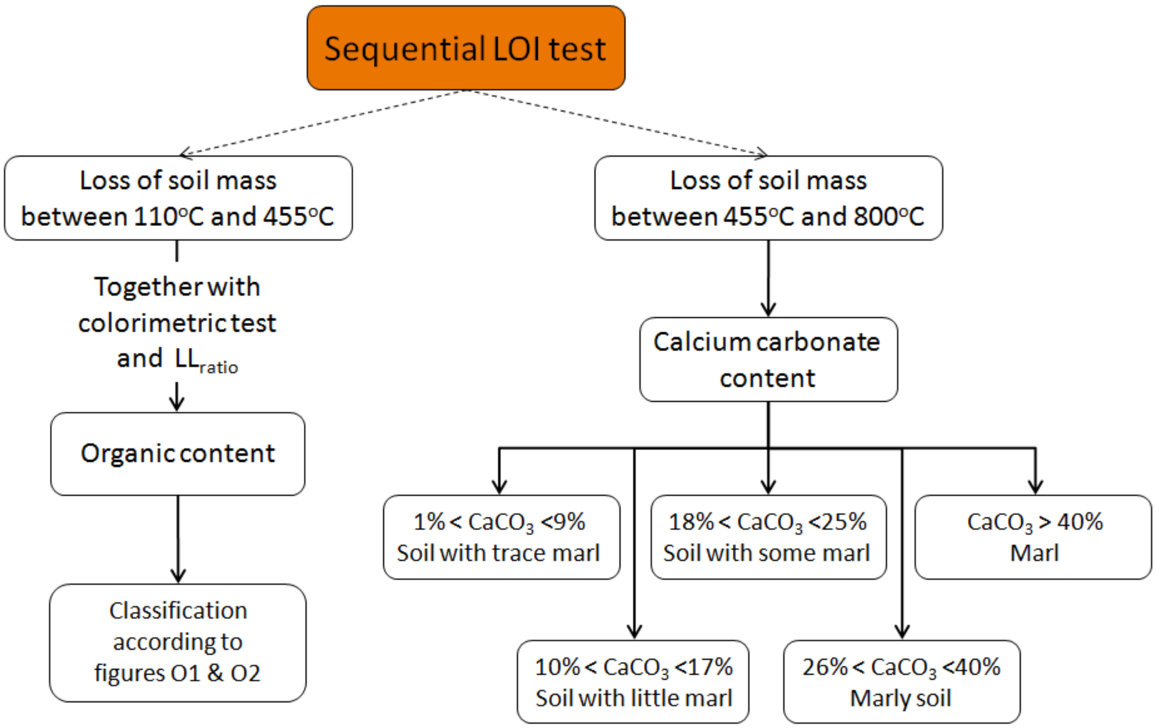
APPENDIX 5

Marls



APPENDIX 5

Combined (Organics & Marls)



“Organics” Classification Procedure & Checklist

___ 1. Perform the Loss on Ignition (LOI) test; (ASTM D2974–07a, AASHTO T267–86)

$$\text{LOI} = \frac{M_{110^{\circ}C} - M_{455^{\circ}C}}{M_{110^{\circ}C} - M_{c}} \times 100$$

M_c = mass of crucible
$M_{110^{\circ}C}$ = mass after oven drying at 110ºC
$M_{455^{\circ}C}$ = mass after burning at 455ºC

___ 2. Classify Soil based on Organic Content using Figure O1:

a) If LOI ≤ 3%, **classify as “*Mineral Soil*”**

b) If 3% < LOI ≤ 15%, GO TO STEP #3 BELOW (follow Figure O2)

c) If 15% < LOI ≤ 30%, **classify as “*Organic Soil*”**

d) If 30% < LOI, **classify as “*Peat*”**

___ 3. Perform Colorimetric Test; (ASTM C40 – 04, ASTM D1544 – 04, AASHTO T21 – 05)

___ 4. Classify Soil based on Organic Content using Figure O2:

a) If color C ≤ 3, **classify only as “*Mineral Soil”***

b) If color C > 3 AND the soil is Coarse Grained with Fine Fraction < 12% (A-1 or A-3 soils), **classify as “*Mineral Soil with Organic Matter*”**

c) If color C > 3 AND the soil is Fine Grained or Coarse Grained with Fine Fraction >12% (A-2 soils), GO TO STEP #5 BELOW

___ 5. Perform Liquid Limit Ratio (LLR) Test; (ASTM D4318 – 10, AASHTO T89 – 10)

$$LL_{ratio} = \frac{LL_{\text{oven dried}}}{LL_{\text{not dried}}}$$

___ 6. Classify Soil based on Organic Content using Figure O2:

a) If LLR > 0.92, **classify as “*Mineral Soil”***

b) If LLR ≤ 0.92, **classify as “*Mineral Soil with Organic Matter*”**

"Marls" Classification Procedure & Checklist

___ 1. Perform the Sequential Loss on Ignition (LOI) test

___ 2. Convert mass loss between 455ºC and 800ºC to $CaCO_3$ content using this equation:

$$CaCO_3 = \frac{100}{44} \times \frac{M_{455°C} - M_{800°C}}{M_{110°C} - M_{c}} \times 100$$

M_c = mass of crucible
$M_{110ºC}$ = mass after oven drying at 110ºC
$M_{455ºC}$ = mass after burning at 455ºC
$M_{800ºC}$ = mass after burning at 800ºC

___ 3. Classify Soil based on $CaCO_3$ content using "Marls" Flowchart:

a) If 1% < $CaCO_3$ < 9%, **classify as "*Soil with Trace Marl*"**

b) If 10% < $CaCO_3$ < 17%, **classify as "*Soil with Little Marl*"**

c) If 18% < $CaCO_3$ < 25%, **classify as "*Soil with Some Marl*"**

d) If 26% < $CaCO_3$ < 40%, **classify as "*Marly Soil*"**

e) If 40% < $CaCO_3$, **classify as "*Marl*"**

APPENDIX 6

“Combined (Organics & Marls)” Classification Procedure & Checklist

___ 1. Perform the Sequential Loss on Ignition (LOI) test

___ 2. Using LOI mass loss after burning at 455^{o}C, follow “Organics” Classification Procedure to obtain Organic Content classification

___ 3. Using LOI mass loss after burning at 800^{o}C, follow “Marls” Classification Procedure to obtain Carbonate Content classification

___ 4. Combine “Organic” and “Marl” classifications to obtain overall classification (see “Combined (Organics & Marls)” Flowchart)

- Example: if Organic Classification is “*Mineral soil with organic matter*”, and
  if Carbonate Classification is “Marly *soil*”, and
  if AASHTO Classification is “*A-7-5”*, then
  classify as “*Marly A-7-5 with organic matter*”

LOSS ON IGNITION (LOI) – Sample Sheet

Soil Sample: ***Soil I***
Location: I69-Sec3 Seg13
Boring No: 3-31-TB-2A
Sample No:
Sample Depth: 30 to 32ft (Bottom)

Date: Sat 10/22/2011
Time: 11:00am
Tested by: AH
Description: Black - silty
455 (6hrs) 800(6hrs)

Test No.	1	2	3	4	5
Crucible No.	A	B	C	D	F
Mass$_{crucible\ empty}$ M_c (g)	17.67	17.94			
Mass$_{crucible\ +\ wet\ soil}$ M_{cws} (g)	34.29	32.80			
Mass$_{crucible\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	30.02	28.44			
Mass$_{crucible\ +\ Ash\ (@\ 455°C)}$ $M_{455°C}$ (g)	29.20	27.47			
Loss on Ignition LOI (%)	*6.6*	*9.3*			

Average Loss on Ignition LOI (%) ____8.0_____

Observations: ______________________________

LIQUID LIMIT TEST (LL) – Sample Sheet

Soil Sample:	***Soil I***	Date:	Thu 10/27/2011
Location:	I69-Sec3 Seg13	Time:	11:30am
Boring No:	3-31-TB-2A	Tested by:	AH/MS
Sample No:		Description:	Black - silty
Sample Depth:	30 to 32ft (Bottom)		455 (6hrs) 800(6hrs)

Oven-dried: ☐ Yes ■ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
Mass$_{\text{tare empty}}$ M_t (g)	1.32	1.30	1.33	1.31
Mass$_{\text{tare + wet soil}}$ M_{tws} (g)	4.90	4.95	4.91	5.60
Mass$_{\text{tare + dry soil (@ 110°C)}}$ M_{tds} (g)	3.57	3.63	3.62	4.07
Water content w (%)	*58.9*	*56.7*	*56.2*	*55.6*
Number of blows N	14	25	29	34

Liquid Limit = ____56.7%____

Observations: ____

____

____

LIQUID LIMIT TEST (LL) – Sample Sheet

Soil Sample: ***Soil I***
Location: I69-Sec3 Seg13
Boring No: 3-31-TB-2A
Sample No:
Sample Depth: 30 to 32ft (Bottom)

Date: Thu 10/27/2011
Time: 11:30am
Tested by: AH/MS
Description: Black - silty
455 (6hrs) 800(6hrs)

Oven-dried: ■ Yes □ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
Mass$_{tare\ empty}$ M_t (g)	1.30	1.34	1.30	1.33
Mass$_{tare\ +\ wet\ soil}$ M_{tws} (g)	5.34	4.89	6.48	6.05
Mass$_{tare\ +\ dry\ soil\ (@\ 110°C)}$ M_{tds} (g)	4.03	3.77	4.86	4.59
Water content w (%)	*47.9*	*46.4*	*45.5*	*44.9*
Number of blows N	16	22	28	33

Liquid Limit = ____46.0%____

Observations: ______________________________

SEQUENTIAL LOSS ON IGNITION (LOI) – Sample Sheet

Soil Sample:	***Soil II***	Date:	Sat 9/17/2011
Location:	I69-sec3 Seg13	Time:	11:45am
Boring No:	3-37-TB-1	Tested by:	AH
Sample No:		Description:	Dark Gray – Clayey
Sample Depth:	24 to 26ft (Bottom)		455 (6hrs) 800(6hrs)

Test No.	1	2			
Crucible No.	CE1	2			
$\text{Mass}_{\text{crucible empty}}$ M_c (g)	19.82	17.71			
$\text{Mass}_{\text{crucible + wet soil}}$ M_{cws} (g)	35.53	33.23			
$\text{Mass}_{\text{crucible + dry soil (@ 110°C)}}$ $M_{110°C}$ (g)	30.03	27.80			
$\text{Mass}_{\text{crucible + Ash (@ 455°C)}}$ $M_{455°C}$ (g)	29.81	27.58			
$\text{Mass}_{\text{crucible + burnt soil (@ 800°C)}}$ $M_{800°C}$ (g)	27.24	25.08			
Loss on ignition LOI (%)	*2.1*	*2.2*			
$CaCO_3$ content (%)	*57.4*	*56.4*			

Average Loss on ignition (%) ____2.1_____

Average $CaCO_3$ content (%) ____56.9____

Observations: ______________________________

____

____

SEQUENTIAL LOSS ON IGNITION (LOI) – Sample Sheet

Soil Sample:	***Soil III***	Date:	Sat 9/3/2011
Location:	Lake George (Hobart)	Time:	11:00am
Boring No:	C6A	Tested by:	AH
Sample No:	T5	Description:	Dark Gray – Soft
Sample Depth:	22 to 24 ft		455 (6hrs) 800(6hrs)

Test No.	1	2	3	4	
Crucible No.	A	B	C	D	
$Mass_{crucible\ empty}$ M_c (g)	17.68	17.94	20.60	18.45	
$Mass_{crucible\ +\ wet\ soil}$ M_{cws} (g)	31.32	32.34	34.74	32.19	
$Mass_{crucible\ +\ dry\ soil\ (@\ 110°C)}$ $M_{110°C}$ (g)	25.42	25.98	28.40	26.01	
$Mass_{crucible\ +\ Ash\ (@\ 455°C)}$ $M_{455°C}$ (g)	24.86	25.40	27.81	25.45	
$Mass_{crucible\ +\ burnt\ soil\ (@\ 800°C)}$ $M_{800°C}$ (g)	24.10	24.58	26.97	24.61	
Loss on ignition LOI (%)	*7.1*	*7.2*	*7.5*	*7.5*	
$CaCO_3$ content (%)	*22.4*	*23.2*	*24.5*	*25.1*	

Average loss on ignition (%) ____7.3_____

Average $CaCO_3$ content (%) ____23.8____

Observations: ______________________________

LIQUID LIMIT TEST (LL) – Sample Sheet

Soil Sample:	***Soil III***	Date:	Thu 9/15/2011
Location:	Lake George (Hobart)	Time:	2:00pm
Boring No:	C6A	Tested by:	AH
Sample No:	T5	Description:	Dark Gray – Soft
Sample Depth:	22 to 24 ft		455 (6hrs) 800(6hrs)

Oven-dried: ☐ Yes ■ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
$Mass_{tare\ empty}$ M_t (g)	1.32	1.32	1.32	1.31
$Mass_{tare\ +\ wet\ soil}$ M_{tws} (g)	5.81	5.41	5.75	5.53
$Mass_{tare\ +\ dry\ soil\ (@\ 110°C)}$ M_{tds} (g)	3.93	3.74	3.98	3.81
Water content w (%)	*72.0*	*69.0*	*66.9*	*68.8*
Number of blows N	17	25	40	34

Liquid Limit = ____69.7%____

Observations: ____

____

____

LIQUID LIMIT TEST (LL) – Sample Sheet

Soil Sample:	***Soil III***	Date:	Fri 9/16/2011
Location:	Lake George (Hobart)	Time:	2:00pm
Boring No:	C6A	Tested by:	AH
Sample No:	T5	Description:	Dark Gray – Soft
Sample Depth:	22 to 24 ft		455 (6hrs) 800(6hrs)

Oven-dried: ■ Yes ☐ No

Test No.	1	2	3	4
Crucible No.	A	B	C	D
Mass$_{\text{tare empty}}$ M_t (g)	1.33	1.32	1.33	1.31
Mass$_{\text{tare + wet soil}}$ M_{tws} (g)	5.54	5.94	5.54	6.25
Mass$_{\text{tare + dry soil (@ 110°C)}}$ M_{tds} (g)	3.88	4.17	3.96	4.41
Water content w (%)	*65.0*	*62.0*	*60.4*	*59.2*
Number of blows N	14	20	27	34

Liquid Limit = ____60.9%____

Observations: ____

____

____

APPENDIX 7

Self Learning Examples:

Soil IV

Site: I-69 sec3 seg12
Depth: 32 to 34 ft
Location: Daviess, IN

LOI = 2.3%
$CaCO_3$ = 2.9%

Soil V

Site: N/A
Depth: N/A
Location: ASTM CL

LOI = 3.6%
> 35% passing sieve # 200
Organic plate no. 5
LL_{ratio} = 0.98
$CaCO_3$ = 4.2%

Soil VI

Site: Lake George Dam
Depth: N/A
Location: Hobart, IN

LOI = 6.8%
> 35% passing sieve # 200
Organic plate no. 5
LL_{ratio} = 0.83
$CaCO_3$ = 21.7%

APPENDIX 8

Classification of Organic Soils and Classifications of Marls: Training Dates

Training Session 1 (Pilot Session)
February 16, 2012
INDOT Materials Testing Facility, Indianapolis, IN

Attendee	Affiliation
Nayyar Siddiki	INDOT, Geotech Dept.
Thomas Nantung	INDOT
Brian Dunbar	INDOT, Geotech Dept.
Iqbal Khan	INDOT
Michael Nelson	INDOT, Greenfield District
Ron Fine	INDOT, Crawfordsville District
Antonio Bobet	Purdue University, Dept. of CE
Marika Santagata	Purdue University, Dept. of CE
Alain El Howayek	Purdue University, Dept. of CE
Sulaiman Dawood	Purdue University, Dept. of CE
Andrew Ferdon	Purdue University, Dept. of CE

Training Session 2
March 16, 2012
INDOT Seymour District Office, Seymour, IN

Attendee	Affiliation
Nayyar Siddiki	INDOT, Geotech Dept.
Brian Dunbar	INDOT, Geotech Dept.
Bill Jarvis	INDOT, Seymour District
Deloris Rieckers	INDOT, Seymour District
Judy Turner	INDOT, Seymour District
Chris Bell	INDOT, Seymour District
Alain El Howayek	Purdue University, Dept. of CE
Sulaiman Dawood	Purdue University, Dept. of CE
Andrew Ferdon	Purdue University, Dept. of CE

APPENDIX 8

Training Session 3
March 30, 2012
INDOT Laporte District Office, Laporte, IN

Attendee	Affiliation
Heather Woods	INDOT, Laporte District
Mike Bramblett	INDOT, Laporte District
Judith Hammons	INDOT, Laporte District
Rhonda Giggy	INDOT, Laporte District
Bob Dahman	INDOT, Ft. Wayne District
Alain El Howayek	Purdue University, Dept. of CE
Sulaiman Dawood	Purdue University, Dept. of CE
Andrew Ferdon	Purdue University, Dept. of CE

Training Session 4
April 3, 2012
INDOT Materials Testing Facility, Indianapolis, IN

Attendee	Affiliation
Jean Hiadari	INDOT
Heather Holder	INDOT
Donna Sipes	INDOT
Linda Spitsyna	INDOT
Brian Dunbar	INDOT, Geotech Dept.
Melvin Hall	INDOT
Youlanda Belew	INDOT
Michael Pritt	INDOT
Jackie Barnes	INDOT
Kulanand Jha	INDOT
David Jacobs	INDOT, Ft. Wayne District
Kellen Heavin	Alt & Witzig Engineering
Geoffrey Thompson	Earth Exploration Inc.
Matthew Brading	ATC
Kenneth Rush III	CTL Engineering, Inc.
Bill Dubois	Patriot Engineering
Abdul Khalaf	Chicago Testing Lab
Alain El Howayek	Purdue University, Dept. of CE
Sulaiman Dawood	Purdue University, Dept. of CE
Andrew Ferdon	Purdue University, Dept. of CE

APPENDIX 9

Feedback Form

	Very Good	Good	Fair
Organization of content	○	○	○
Clarity of presentation	○	○	○
Depth of material covered	○	○	○
Language and Visual effects used	○	○	○
Ease in comprehending the classification table	○	○	○
Effectiveness of examples provided	○	○	○
Sufficiency of handouts	○	○	○
Met your expectation	○	○	○
Overall rating of the presentation	○	○	○

Please provide additional comments: