

**RESEARCH PROBLEM STATEMENT**

<b>DATE:</b> 09/06/2019	<b>PROJECT AREA:</b> Materials
<b>TITLE:</b> Investigating Rapid Soil Moisture Content Determination Methods	
<b>PROBLEM STATEMENT:</b> <p>Moisture content is a critical parameter that must be carefully controlled during earthwork operations to ensure the proper performance of fills and subgrades. Conventional methods (e.g., oven drying, pan drying, nuclear gauge) are not always reliable, may cause delays in construction, and may require special certifications, handling, and radiation monitoring. While the nuclear gauge has become very popular due to the ability to easily and rapidly obtain both moisture content and density, the regulations and handling requirements make it a hassle to own and operate. There is a need for a method which is just as reliable as the nuclear gauge without all of the regulatory burdens. There are a number of existing studies which have demonstrated the benefits of technologies such as time domain reflectometry (TDR), capacitance measurements, tensiometers, and resistance measurements. However, most of these studies only considered one or two soil types and very little priority was given to methods that do not require soil specific calibrations (which makes many methods time prohibitive). A thorough review of all the promising methods is needed which takes these factors into account.</p>	
<b>OBJECTIVES:</b> <ol style="list-style-type: none"> <li>1. Evaluate all of the promising methods from existing studies in the literature, as well as emerging technologies not yet applied to determine accuracy and ease of use.</li> <li>2. Determine the most accurate and rapid method or combination of methods.</li> <li>3. Develop testing and procedure manual and training module.</li> </ol>	
<b>FORM OF RESEARCH IMPLEMENTATION AND RETURN ON INVESTMENT:</b> <ol style="list-style-type: none"> <li>1. Operator's manual detailing method, procedures, and details needed to perform selected techniques.</li> <li>2. Field ready measurement system to perform moisture content and density determination.</li> <li>3. Training module and on-site training for use of equipment and procedures.</li> </ol>	
<b>Estimated Project Duration:</b> 24 Months	
<b>PREPARED BY:</b> Michelle L. Bernhardt-Barry	
<b>AGENCY:</b> University of Arkansas	
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Standing Subcommittee  
Ranking

Advisory Council  
Ranking

Statement Combined with  
Statement Number(s)

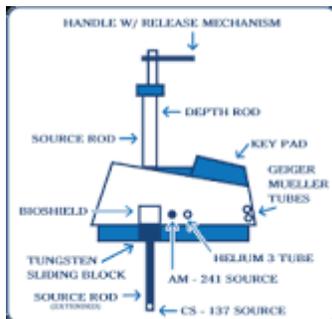
# Investigating Rapid Moisture Content Determination Methods

ARDOT Problem Statements FY-2021

**Moisture Content** is one of the most critical parameters for proper performance of fills and subgrades.

## Conventional Methods

- Oven drying
  - very accurate
  - takes 24 hours which delays construction
  - requires removal of sample which is labor intensive
- Pan drying
  - faster version of oven drying, but still takes extended amounts of time
  - not as accurate
  - requires constant attention/labor intensive
- Nuclear density gauge
  - not as accurate or reliable as oven drying
  - obtain moisture content and density quickly and easily
  - most commonly used method because of ease



## Disadvantages of Nuclear Gauge

- Radioactive source could pose a potential hazard if not properly used
- Requires regulations for transportation, use, and storage
- Training and logging regulations are time intensive
- Ensuring compliance with regulations can require additional resources and time

There is a need for a method that is as reliable as the nuclear gauge without all of the regulatory hassles and concerns.

# Other Emerging Methods

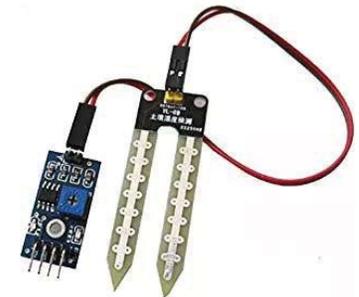
- **Electrical Density Gauge (EDG)**
  - measures density and moisture content without a nuclear source
  - requires separate calibration with each material tested
- **Time Domain Reflectometry (TDR)**
  - measures travel time of electrical pulse and relates it to dielectric constant of the soil
  - requires separate calibration with each material tested
- **Capacitance sensors**
  - measures resonant frequency which relates to a soils dielectric constant
  - requires separate calibration with each material tested
- **Resistive sensors**
  - measures current passing across probes which relates to the resistance value
  - requires information about the soil at different moisture contents in order to achieve a specific value



Capacitance sensor



Resistive sensor



## Research Goal and Objectives

**The goal of this study is to develop a rapid method to obtain moisture and density for different soil types during earthwork operations.**

- Evaluate all of the promising methods from existing studies in the literature, as well as emerging technologies not yet applied to determine accuracy and ease of use.
- Determine the most accurate and rapid method or combination of methods.
- Develop testing and procedure manual and training module.

# Proposed Research Tasks

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1. Conduct a review of all existing devices and methods which show promise in rapid determination of moisture content and density
  - Moisture content determination is the main goal, but the final method must also provide density results too in order to compete with (and replace) the nuclear density gauge
2. Compare the accuracy and speed of the methods obtained in step 1 with the nuclear density gauge and oven drying method
  - At least 5 soils will be tested at a range of water contents (gravel clay mixture, sand, sand clay mixture, lean clay, high plasticity clay)
  - Calibration difficulty and time will be factored into these times and priority will be given to simple systems which do not require soil specific calibrations
3. Choose the most efficient and accurate method or combination of methods to achieve rapid moisture content readings
  - It may require a combination of methods for which a sensor system will be developed for use by ARDOT
4. Develop a measurement system, corresponding operator's procedure manual, and training module for use of the system

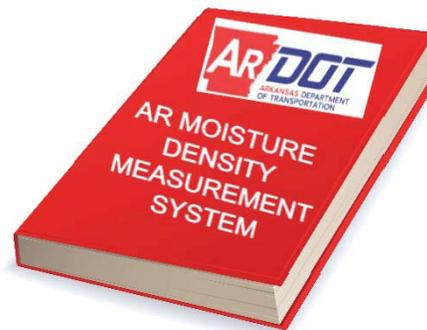
# Implementation and Deliverables

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- Operator's Procedure Manual detailing method(s), procedures, and items needed to perform selected techniques
- Field ready measurement system to perform moisture content and density determination
- Training module, as well as on-site training for use of equipment and procedures



Moisture/density system



Operator's manual



- Reduce regulatory requirements of nuclear gauge
- Save time and money

**RESEARCH PROBLEM STATEMENT**

<b>DATE:</b> 09/09/2019	<b>PROJECT AREA:</b> Materials
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**TITLE:** Non-nuclear Moisture Content and Density Determination

**PROBLEM STATEMENT:**

The nuclear density gauge is the most commonly used device to rapidly determine the moisture content and unit weight of subgrade soils, base courses, and asphalt pavements. Use of the nuclear density device requires special permitting, special training, and may expose the user to additional amounts of radiation. Although trying to reduce the use of nuclear density devices has been of interest to the Arkansas Department of Transportation (ARDOT), previous research projects (MBTC 2075, TRC1301) that were performed found that while the currently available non-nuclear technologies (Humboldt Electrical Density Gauge and TransTech Soil Density Gauge, TransTech Pavement Quality Indicator, Troxler PaveTracker) were capable of accurately determining the density of the soil/asphalt, the devices were not able to accurately determine the moisture content of the soil. A non-nuclear method to accurately and rapidly determine the moisture content of soils is needed. The Veris U3 is proposed; it is capable of providing simple, scalable, high definition field scanning (soil mapping) . This technology has been used farming but an investigation is to see if it is appropriate for construction.

**OBJECTIVES:**

The objective of this research project is to develop a non-nuclear method to rapidly and accurately determine soil moisture and density on a job-site basis rather than a point-wise basis. The use of Veris technology is proposed. The compact size of the Veris U3 device enables it to be pulled through roadway subgrade and base course with an all-terrain vehicle like a John Deere Gator or a dozer. The U3 uses infrared soil optics to obtain nitrogen and water insights, the SpeedRead pH sensor is used to capture pH potential, and the electrical conductivity sensor is used to measure electrical conductivity. The downforce on the sensor is anticipated to be correlated to the density of the soil.

**FORM OF RESEARCH IMPLEMENTATION AND RETURN ON INVESTMENT:**

This research will be implemented through the use of the Veris U3 device instead of the nuclear density gauge. A users manual and demonstration on the use of the U3 for determination of moisture content and density will be provided. Cost savings will be realized through a reduction in expenses 1) associated with required yearly nuclear training/certification courses, 2) related to maintenance and calibration of existing devices and procurement of new nuclear devices.

**Estimated Project Duration:** 24 Months

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**REVIEWER:**

Standing Subcommittee  
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Statement Number(s)

# Non-nuclear Moisture Content Determination



UNIVERSITY OF  
ARKANSAS

Richard Coffman, PhD, PE

- **Moisture content and unit weight** are required construction quality control parameters.
- **Nuclear Density Gauges:**
  - most commonly used tool to determine moisture content and unit weight,
  - require special permitting,
  - require special training,
  - may expose user to radiation.
- **Problem Statement:** a non-nuclear alternative is needed measure the moisture content and density. Alternative applicable for:
  - subgrade soils,
  - base courses,
  - asphalt pavements.



Troxler Nuclear Density Gauge

# Previous Research at AHTD

- **TRC 1301 devices tested:**
  - Humboldt Electrical Density Gauge
  - TransTech Soil Density Gauge
- **MBTC 2075 devices tested:**
  - TransTech Pavement Quality Indicator
  - Troxler PaveTracker
- **Findings:**
  - Acceptable measurement of unit weight
  - Unacceptable measurement of water content



Humboldt Electrical Density Gauge



TransTech Pavement Quality Indicator



TransTech Soil Density Gauge



Troxler PaveTracker

## Proposed Research

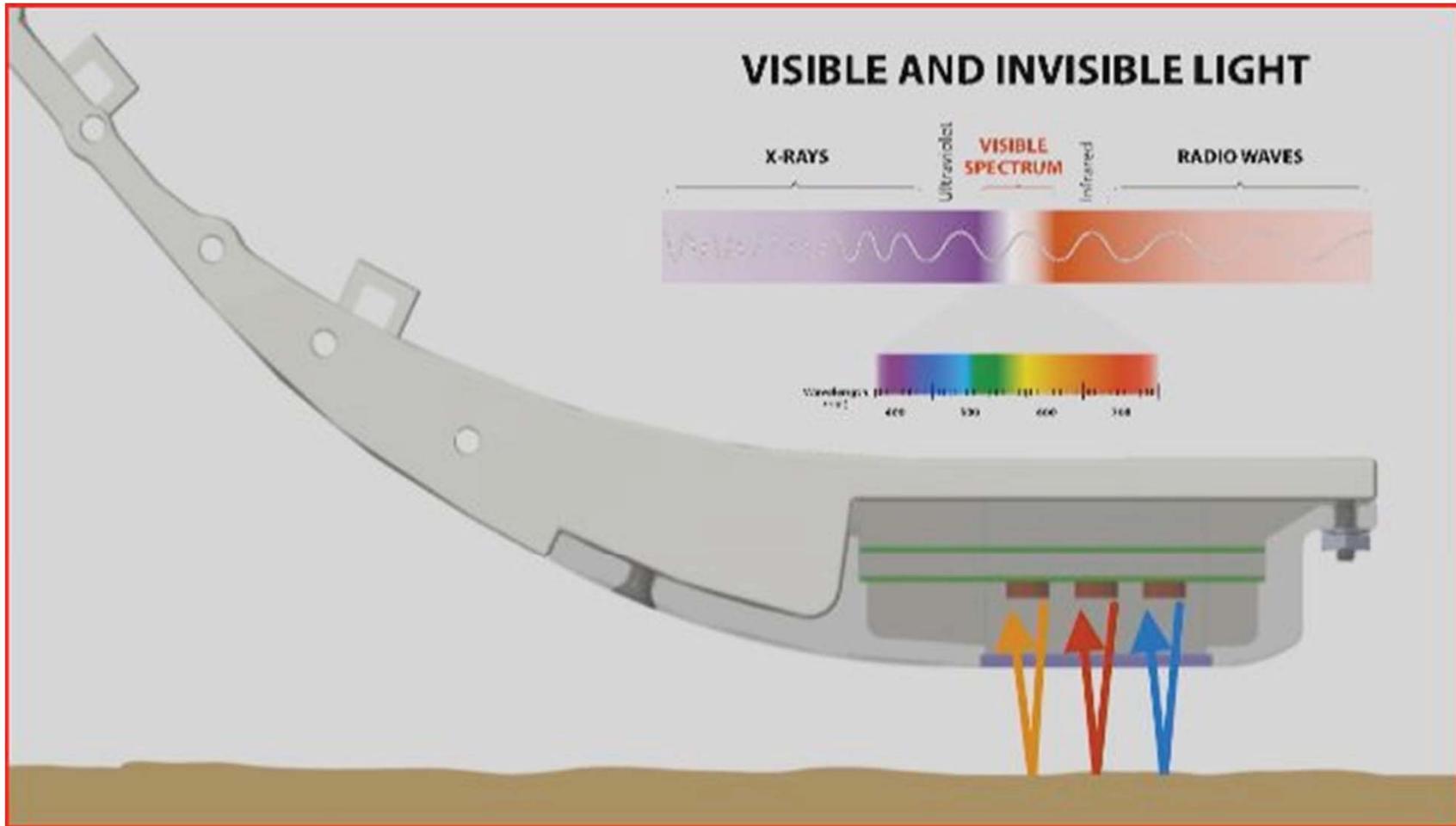
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- **The goal of this study is to develop a non-nuclear method to rapidly and accurately measure moisture content and density using infrared optics.**
  - Water Content from Infrared Optics
  - Density from Downforce



Infrared Soil Optics  
N and H<sub>2</sub>O Insight.

[https://www.youtube.com/watch?v=\\_sdBH4yHObs](https://www.youtube.com/watch?v=_sdBH4yHObs)



<http://www.wolffarmsprecision.com/news-view/smartfirmer-to-be-beta-tested/>

## Implementation

- Infrared optics determination of moisture content.
- Users manual on use of Veris U3 for moisture content and density determination.
- Demonstration of Veris U3 for moisture content and density determination.