The Electrical Density Gauge
Past, Present and Future

Presented by
Dennis M Anderson, P.E.
Electrical Density Gauge, LLC
EDG Development

Development of the:

ELECTRICAL DENSITY GAUGE (EDG)

ELECTRICAL PROPERTIES OF SOIL AND GEOTECHNICAL ENGINEERING
EDG Development

The project spanned over 19 years of work from the initial research to the commercialization of a new geotechnical engineering technology for the determination of in-situ density and moisture content of soil for use in civil engineering.
EDG Theory

Every soil type has a unique geo-electric signature. When this signature is researched and established for a given soil type and integrated with physical properties, then that data may be used to determine geotechnical field characteristics of the soil under test. Several factors influence the electrical character of a soil, such as:

1. Physical properties, i.e. compaction and water content
2. Mineralogy
3. Soil chemistry and weathering
4. Chemistry of the wetting agent, i.e. salts
Development Timeline

1992  First idea to use electrical geophysics in geotechnical engineering which could be developed for applications in soil engineering

1992  Anderson enrolls in University of Nevada to carry out independent study of the technology on Measuring Hydraulic Conductivity of Clay Liners using electrical geophysics, Project Thesis in 1993
Development Timeline

1992  The research was based on three primary principals of applied geophysics:

1- Conrad and Marcel Schlumberger (1930)
2- G.E. Archie’s 1941 work
3- Tixier (1949) and Wyllie and Rose (1950)

Three principals combined and expanded
1993  Research paper completed and afforded an engineering answer to calculate hydraulic conductivity in soil

1994-98  R&D carried out to develop a commercially acceptable machine and three patent application made to the US Patent and Trademark Office.
1996  

**Eureka moment !!!**

The question was asked,

“what else can you do with this technology?”

Soil moisture content and probably soil density
Development Timeline

1999  Patent 5,861,751 for the use of electrical geophysics for soil and moisture determination

    Patent 5,861,750 for the use of electrical geophysics for measuring hydraulic conductivity.
United States Patent

Anderson et al.

[54] ELECTRICAL GEOPHYSICAL METHODS AND APPARATUS FOR DETERMINING THE IN-SITU DENSITY OF POROUS MATERIAL

[76] Inventors: Dennis M. Anderson, P.O. Box 140; William J. Eblan, P.O. Box 4230, both of Canton City, Neb. 68822

[21] Appl. No.: 851,569
[22] Filed: May 6, 1997

Related US Application Data

[00] Provisional application No. 60/317,277, May 13, 1996.

[51] Int. Cl.* ................................. G01 V 306
[52] U.S. Cl. .............. 324/347, 324/715, 324/323, 73/152.06

[58] Field of Search .............. 73/38, 152.05, 73/152.06, 152.07, 324/715, 71.7-71.8, 375, 376, 347

[56] References Cited

U.S. Patent Documents
3,862,177 9/1975 Walker .................. 324/376
4,106,244 8/1978 Wood .................. 324/123
4,007,848 3/1977 Green .................. 73.38
5,206,068 5/1993 Collins .................. 73.38

OTHER PUBLICATIONS
1956 Handbook of Physical Constants, Clark, Sec. 2a, Keller, G.V. Late Properties of Rocks, pp. 553-571, Equation # 3.55.

Primary Examiner—Jose Rojas
Assistant Examiner—Jose M. Salas

ABSTRACT

The invention includes a method and device for determining the in-situ density of a porous material. A resistivity measuring device applies an electrical current through an electrode array to measure the resistivity of the porous material. The resistivity measuring device may also be used to measure the resistivity of a pore filling fluid. A formation factor and in-situ density constants of the porous material are determined using empirical methods. In-situ moisture content of the porous material is determined. The above data is applied to a general geophysical in-situ density equation to calculate the in-situ density of the porous material.

12 Claims, 3 Drawing Sheets
## Development Timeline

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>The Electrical Density Gauge Limited Liability Company was formed and capitalized to commercialize the new density technology.</td>
</tr>
<tr>
<td>2001</td>
<td>First presentation to ASTM D 18.80 Subcommittee on Rocks and Soil.</td>
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<td>2000-04</td>
<td>Product R&amp;D continued with ten beta units sent out to DOT laboratories and Universities for trial.</td>
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<td>2005</td>
<td>US Patent 6,963,205 titled Electrically Measuring Soil Dry Density was issued to the electrical density gauge research team.</td>
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<td>2006</td>
<td>Draft standard was submitted to the ASTM D 18.08.03 Subcommittee on Rocks and Soil and analysis of non-nuclear density technologies.</td>
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Development Timeline

2005  Formed a business relationship with Humboldt Mfg.
2006  Development and production of EDG model C
2009 - 2010 – 2011

The EDG Model C becomes Humboldt's single most successful selling product with over 700 sold to over 30 different countries.
2011  ASTM D7698 – 11 Standard Test Method for In-Place Estimation of Density and Water Content of Soil and Aggregate by Correlation with Complex Impedance (ten years after 1st ASTM presentation)

2014  AASHTO Provisional Standard T112 issued in August and a set of Department of Transportation across the USA are participating in an evaluation program
Development Timeline

2012  EDG SD model available for commercial use
The EDG determines certain electrical properties of the soil by transmitting a 3.0 MHz radio frequency signal into the soil through a set of steel probes (darts) driven into the soil.

The electrical signal is less than a cell phone and very safe for use in all application.
EDG in Practice

EDG

Test Probes connect opposite pairs

Temp Probe

Dart Depth = lift depth
EDG in Practice
Material electrical properties are established by conducting pre-construction geotechnical tests.

A series electrical field measurement are related to a set of other conventional field test to establish the relationship of the soil’s electrical properties to the soil’s physical properties.

The process of establishing the soil material’s electrical signature is called the “Soil Model.”

After a Soil Model is completed the EDG is used to measure the soil electrical properties during a Job Site test. These measurements are then used to calculate the soil’s density and moisture.
The 3.0 MHz radio frequency transmission signal is used to measure the soil current, voltage, phase and temperature.

The onboard computer calculates the soil’s temperature corrected capacitance, resistance and impedance, Z versus density.

The calculation relate a linear regression of the impedance to the soil density and a second linear regression of the capacitance over the resistance to the water content C/R versus water content.
Building a Soil Model
EDG – Wet Density

Wet Density vs Impedance

\[ y = -0.4057x + 2441.9 \]
\[ R^2 = 0.981 \]
EDG - Moisture

Water Mass Per Unit Volume vs C/R

\[ y = 2402.9x - 2.3965 \]
\[ R^2 = 0.9788 \]
Soil Model Editing

Soil Model Not Edited
Soil Model Editing

Soil Model Edited
## Sand Cone

### Carson By Pass 25 Feb. 2014 Sand Cone Tests

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<th>Compaction</th>
<th>Moisture (%)</th>
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### NDOT Tests

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<th>Difference</th>
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**Sum** | **-10.3** | **-9.3** | **-12.5** |

**Average** | **-1.3** | **-1.2** | **-1.6** |
New Electrodes

Surface plates

Surface Rods
EDG Reported Values

The EDG reports:

- Wet Density
- Moisture Content

and by calculation:

- Dry Density
- Relative % compaction
Verification Data

The data for verification of the EDG was taken over a 3 year period from 230 tests from 34 different sites.

Compared to NDG results, the EDG shows a variation of +/- 2.65% for density and +/-1.55% for moisture content.
Verification Data

Water Content Histogram
CIMI Vs. Nuclear

% Relative Difference between CIMI vs Nuclear Density Gauge
Continuing Development

On-board Soil Model Optimization Program (implementation in 2015)

Laboratory to Field Calibration – using standard compaction molds (additional testing and implementation in 2015)

Expanding soil model algorithms – reducing the need for Soil Models

Asphalt Testing (prototype in 2015)
Summary

Proven development path over 19 years

Industry acceptance by ASTM D7698 – 11, and

AASHTO Provisional Standard T112 (2014)

Significant use worldwide in over 40 countries