CURRENT USERS OF THE HUMBOLDT GEOGAUGE™

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HUMBOLDT MFG. CO.
7300 WEST AGATITE AVENUE
NORRIDGE, ILLINOIS 60706-4704

Scott Fiedler, Product Manager
Humboldt Mfg. Co.
7300 West Agatite Ave., Norridge, IL 60706, U.S.A.
800-544-7220 extension 231 (Voice)
708-456-0137 (Fax)
fiedler_hmc@msn.com (Email)

Melvin Main, Marketing
Main Associates
16 Vegas Dr., Hanover, PA 17331, U,S,A.
717-637-8246 (Voice & Fax)
main@cyberia.com (Email)

Following is a partial list of who has or who is currently using the Humboldt GeoGauge. It is provided so that all the users might share their experiences and thereby derive more benefit for the their use of the GeoGauge. Please remember that not all users are advocating the GeoGauge, but simply evaluating it in the light of its potential value. Please respect their sense of propriety. Some may not want to talk too much about what they are doing. Not listed here are the international users in such countries as the UK, Scotland, Canada, France, New Zealand, South Africa and Venezuela. If there are errors or inaccuracies in the information below, please contact those on the cover page.

Site: **University of Missouri**
Kansas City, MO
Contact: Dr. Anil Misra, (816) 235-1285

Span: 7/98 to present

Goals: 1) Develop a field method for characterizing the stiffness of Fly Ash C stabilized subgrades.
2) Characterize the stiffness of the same subgrades to facilitate the development of performance specifications and process control methods.

Projects:
a) Highway construction, City of Overland Park, KS
b) Highway construction, City of Blue Springs, MO
c) Highway construction, Jackson County, MO
d) NASCAR race track construction, Kansas City, MO (Fills will be up to 60' deep.)
e) Power plant rail spur construction, Hawthorne, MO

Work is being done in cooperation with HNTB, Inc and Alpha-Omega GeoTech of Kansas City, KS.

Companions: Cores for various laboratory tests, density via nuclear gauge, Proctor, moisture via Speedy Moisture gauge and triaxial tests (including resilient modulus).

Results: Weather, funding and contractor issues have repeatedly delayed work. Data gathered to date clearly shows that the GeoGauge is capable of enabling the goals.

Site: **NCDOT**
Raleigh, NC
Contact: C.K. Su, (919) 733-3242

Span: 8/98 to present

Goal: Develop a field method for characterizing the stiffness of highway bases and subgrades in preparation for developing modulus based specifications.

Projects: 1) Two-highway construction sites in North Carolina's Piedmont geological region.

2) Other possible highway sites in North Carolina's coastal and mountain geological region.

Companions: Field-Tests - density nuclear gauge (with moisture content measurement), FWD, Conventional Ring Density Test and Clegg Hammer Test. Laboratory Tests - Resilient Modulus Test (Shelby tube sample and remolded sample), Proctor and California Bearing Ratio.

Results: A very large amount of data has been collected to date. The data gathered to date clearly shows that the GeoGauge is capable of enabling the goal. Contractual commitments have not allowed a comprehensive analysis of the data until recently. Some of this data was used by Humboldt to validate an analytical-empirical relationship between stiffness, density and moisture content.

Site: **H.C. Nutting Co.**
Cincinnati, OH
Contact: C. Dumford, (513) 321-5816

Span: 8/98 to 5/99

Goal: Develop a non-nuclear means of controlling compaction.

Projects: 1) Base and subgrade on US Highway 35 near Xenia, OH.
2) Structural fills on pipelines and foundations

Companions: Density nuclear gauge, Proctor, plate load test, Menard Pressure Meter test and, California Bearing Ratio.

Results: All of the data was used by Humboldt to validate an analytical-empirical relationship between stiffness, density and moisture content. Sufficient correlation between measured density and density estimated from stiffness and moisture content that the estimated density was judged an alternative method for controlling compaction. This method was judged to be viable when a field instrument for measuring moisture content, as quick and simple as the GeoGauge, is available.

Site: **City of San Jose**
San Jose, CA
Contact: R. Coco, (408) 277-4513

Span: 7/98 to 11/98

Goal: Develop a non-nuclear means of controlling compaction.

Projects: The infrastructure of a 10,000-acre subdivision. This included roadways, buried structures, foundations, trenches, and backfills.

Companions: Density nuclear gauge, with moisture content (At least several GeoGauge measurements were made for each nuclear gauge. ASTM and

Caltran standard procedures were followed, which included performing a modified Proctor to establish traceability for the density measurements.)

Results: All of the data was used by Humboldt to validate an analytical-empirical relationship between stiffness, density and moisture content. Sufficient correlation between measured density and density estimated from stiffness and moisture content that the estimated density was judged an alternative method for controlling compaction. This method was judged to be viable when a field instrument for measuring moisture content, as quick and simple as the GeoGauge, is available.

Site: **Ohio Research Institute for Trans. & The Environ., Ohio University**
Athens, OH
Contact: Dr. S. Sargand, (740) 593-1467

Span: 8/98 to present

Goals: 1) Develop a new way to monitor and effect control of subgrade construction. (The major issue is the variability in highway subgrade performance relative to "mature " failures. They want some way to reliably measure stiffness and/or modulus.)
2) Characterize the installation process of plastic and corrugated steel pipe of varied sizes and descriptions as the basis for improving the processes that influence the soil/pipe performance.

Projects: 1) FHWA funded, OHDOT managed test project to control the variability in subgrade stiffness/modulus.
2) Test installations of plastic and corrugated steel pipe. The DOTs of OH, PA, KY and WV are directly involved. Six pipe manufacturers are involved, including ADS. Ohio University will provide the labor to perform the field measurements and data analysis.

Companions: Project 1): The GeoGauge will be one of 4 measurements evaluated. The others are the FWD, DCP and a German plate load test. Density/moisture will be measured via a nuclear density gauge and various, yet to be specified, laboratory tests.
Project 2): Density & moisture via nuclear density gauge, Proctor and others, yet to be specified.

Results: Project 1) is complete with a report being written. Preliminary results, provided during 9/99, indicated very good correlation between GeoGauge measurements and the measurements using the other methods. GeoGauge measurements were judged to be highly repeatable. The GeoGauge was judged a suitable method for enabling the stated goal. Project 2) is just underway.

Site: **TXDOT**
Austin, TX
Contact: D.H. Chen, (512) 467-3963

Span: 6/98 to present

Goal: Conclusively establish a reliable field method for measuring soil resilient modulus.

Projects: Various in TX

Companions: Laboratory Tests - resilient modulus and Proctor. Field Tests - density & moisture via nuclear density gauge, FWD, SASW and D-SPA.

Results: This project is complete and a report has been issued. The report states that quality control using density is inconsistent with pavement design. It states that the GeoGauge has the potential to be used to enable quality control on a production basis. Excellent correlation was established between GeoGauge determined modulus and that determined from the other methods. The report also categorizes base quality using GeoGauge measurements. Plans are under way to confirm these results on a statewide basis and introduce this means of quality control to TXDOT districts. Other work continues with the GeoGauge by TXDOT's Materials Dept.

Site: **FDOT**
Gainesville, FL
Contact: Dr. R. Ho or David Horhota, (352) 337-3206

Span: 8/98 to present

Goals: 1) Improve material control primarily in those areas where crushed limestone is used to stabilize soil. Presently, FDOT uses a LBR (Limestone Bearing Ratio, modified CBR) to do the evaluation and that method takes a week, too long.
2) Develop a non-nuclear means of controlling compaction.
3) Develop a method for enabling compaction process control.

Projects: Highway sites in northwestern, northeastern and southern FL. Measurements will be made on the subgrades, bases and embankments

Companions: Laboratory Tests - resilient modulus, LBR and Proctor. Field Tests - density & moisture via nuclear density gauge, Clegg Hammer and SPA.

Results: Most of the data has been used by Humboldt to validate an analytical-empirical relationship between stiffness, density and moisture content. Sufficient correlation between measured density and density estimated from stiffness and moisture content that the estimated density was judged an alternative method for controlling compaction. This method was judged to be viable when the GeoGauge is used in companion with the Speedy

Moisture Gauge. The University of Florida has been contracted to independently confirm these results using the data collected to date.

Preliminary results show that a correlation exists between laboratory determinations of modulus, made with the GeoGauge and that made with LBR measurements. Improvements in the GeoGauge laboratory set up are being made to improve the correlation to the level of a viable method.

Bases and subgrades are being characterized with the GeoGauge during and after construction. The University of Florida has been contracted to develop a process control method using the data.

Site: **MODOT**
Jefferson City & Rolla, MO
Contact: Jerry Hirtz, (573) 751-7600 or Jim Knutelski, 573-368-2567

Span: 7/98 to present

Goals: 1) Find a non-nuclear method of controlling compaction.
2) Find a test method suitable for developing a database that will form the basis of a MODOT stiffness/modulus specification for evaluating fills.

Projects: Highway sites in several MODOT districts.

Companions: Nuclear density vs. stiffness measurements will begin immediately. Correlation to resilient modulus and FWD will come later as a more formal plan is generated.

Results: All of the data was used by Humboldt to validate an analytical-empirical relationship between stiffness, density and moisture content. Sufficient correlation between measured density and density estimated from stiffness and moisture content that the estimated density was judged an alternative method for controlling compaction. This method was judged to be viable when a field instrument for measuring moisture content, as quick and simple as the GeoGauge, is available.

The evaluation of the GeoGauge for the second goal is complete. The preliminary analysis of the data appears favorable to the GeoGauge.

Site: **FHWA, Turner-Fairbanks Highway Research Facility**
McLean, VA 22101
Contact: Al DiMillio, (202) 493-3035

Span: Permanent (sale)

Goal: The FHWA wants to explore simpler, faster and more convenient ways of controlling compaction. They would like to see if controlling engineering properties like stiffness and modulus is possible.

Projects: Various prepared materials at the Turner-Fairbanks Research Facility. The FHWA has been Humboldt's partner in the development of the GeoGauge. It is currently promoting the national evaluation of the GeoGauge.

Companions: Density & moisture via nuclear density gauge.

Results: All of the data was used by Humboldt to validate an analytical-empirical relationship between stiffness, density and moisture content. The correlation between measured density and density estimated from stiffness and moisture content that the estimated density is being independently reviewed.

The FHWA has been instrumental in facilitating many of the current and past evaluations of the GeoGauge.

Site: **MnDOT**
1400 Gervais Ave., Maplewood, MN 55109
Contact: John Siekmeier, 612-779-5299

Span: 7/95 to present

Goals: 1) Develop a method for improved compaction control for buried structures. Control properties like stiffness and modulus if possible.
2) Develop a field method for measuring subgrade and base modulus that is capable of enabling quality control.

Projects: Various highway and underground structures

Companions: Density, moisture content, proctor, DCP, FWD & Loadman portable FWD.

Results: The work in buried structures is on going. A report has been issued. The report states that soil stiffness play a significant role in the performance of buried structures. GeoGauge measurements appeared to correlate with structural performance.

The work in soil characterization is on going. A report has been issued. The report states that conventional density based compaction tests are not a good measure of performance when the compacted material is nonuniform. It also shows a good correlation between the modulus determined from GeoGauge measurements and that determined for the other methods. It recommended the continued transition to modulus based mechanistic designs supported by testing of material and pavement system modulus.

Site: **Rutgers University**
Brunswick, NJ
Contact: Tom Bennert, 732-445-2645

Span: 12/98 to present

Goal: Develop the means to control the compaction of a concrete stabilized fill of dredged silt.

Projects: Rutgers is being funded by NJDOT. The fill is 85% silt, dredged from NY harbor, and 15% Portland cement. NJ is currently using this material as a fill for embankments. The silt starts with 200% moisture content, the mixture is initially 100% and then an optimal 45% after days of "curing". NJDOT needs a non-destructive way to monitor stiffness as the fill "cures", coming back to specific locations for repeated measurements. Most density measurements are destructive. Nuclear gauges do not provide accurate dry density reading on materials containing Portland cement.

Companions: Density, moisture content, DCP & Clegg Hammer.

Results: Results will not be forthcoming until a NJDOT approved report is released.

Site: **Williams Earth Sciences**
10600 Endeavor Way, Largo, FL 33777
Contact: Ramanuja Kannan, 727-541-3444

Span: 10/98 to present

Goal: Improve compaction control primarily in those areas where crushed limestone is used to stabilize the subgrade. Possibly replace LBR & Proctor measurements with a less time consuming measurement.

Projects: Williams is being funded by FDOT, District#2. Work will take place primarily on 40 miles of new highway north of Tampa, FL.

Companions: Density, Moisture content, LBR & Proctor.

Results: Williams has chosen not to communicate their results to Humboldt.

Site: **Koch Materials Co.**
415 North 10th Street, Terre Haute, IN 47807-3619
Contacts: Susan McFarland, (812) 232-0421 x28, Todd Thomas, 316-828-6737 or Kevin McGlumphy, 404-363-9146

Span: 3/99 to present

Goals: 1) Characterization and control of cold mix asphalt physical properties so as to expand the role of the materials to paving
2) Replacement of complex laboratory tests

Projects: Koch is conducting field tests on 1 1/2" to 4" thick material. They are coupling the field tests with lab tests to see if the change in stiffness as a function of cure time can be related to moisture content. The field work is being conducted in Georgia and Texas.

Companions: Density, Moisture content, Marshall tests & Hveen tests.

Results: The GeoGauge has enabled Koch to monitor the chemical reaction of the mix so as to determine when the reaction is sufficiently complete to begin compaction. It has also enabled the monitoring of compaction so as to determine when compaction begins to diminish with sustained compactive effort.

Preliminary laboratory testing show a good correlation between asphalt strength as measured by conventional means and modulus as determined from GeoGauge measurements. Discussions have been initiated regarding how the GeoGauge might be an alternative to conventional laboratory methods.

Site: **ATR Institute, University of New Mexico**
Albuquerque, NM 87106
Contact: Lary R. Lenke, Associate Director, (505) 277-3102

Span: 8/99 to present

Goal: Develop a non-nuclear method of controlling compaction for the NMDOT.

Projects: Various laboratory projects over 2 years and 6 NMDOT districts. The first phase will be to confirm the operation of the GeoGauge per Humboldt's performance claims. Other phases will be planned pending the outcome of phase 1.

Companions: Density, Moisture content & others.

Results: Through sophisticated yet direct mechanical and analytical means, the precision, bias and depth of measurement of the GeoGauge has been confirmed. A preliminary report has been issued. Release of the report is pending internal review.

Planning for phase 2 of the project has begun.

Site: **Maryland State Highway Administration**
Brooklandville, MD 21022
Contact: William Adzimahe, (410) 321-3789 or Bob Kochen, (410) 321-4090

Span: 12/99 to present

Goal: Develop a way to specify and control the use of a soil-fly ash-cement mixture.

Projects: Reconstruction of US 113 from the Delaware line to Salisbury, MD. Work will be done during and after construction on the subgrade, two 6" lifts of soil-fly ash-cement mixture and 2" to 6" of asphalt pavement. The work will include a demonstration of capability, correlation of GeoGauge measurements with density, FWD & laboratory strength tests, in-place material characterization and the development of in-place evaluation/process control methodology.

Companions: Density, Moisture content, FWD & laboratory strength tests.

Results: Laboratory and field demonstrations have indicated that the GeoGauge has the capability of enabling the goal. The testing for material characterization and measurement correlation is planned for 1/00.

Site: **Fluid Sciences. LLC**
102 Magnate St., Lafayette, LA 70508
Contact: Mike Grotefend, (318) 264-9448

Span: 7/99 to present

Goals: 1) Develop a method to specify, evaluate and control the installation of soil that stabilized with their organic polymer system.
2) Develop a method to customize stabilization solutions.

Projects: Various secondary road rehabilitation in the south central US. The GeoGauge is to be included in a CERF/HITECH evaluation of stabilization agents through Fluid Sciences. A laboratory method is to be developed that will cure rates, ultimate modulus and index values for field installations to be determined for custom solutions.

Companions: Density, Moisture content & DCP

Results: Fieldwork to date has show that the GeoGauge is capable of enabling the goals. The laboratory work shows promise with the reliability of the mechanical setup for the test samples being the primary issue.

Site: **Midwest Industrial Supply, Inc.**
PO Box 8431, Canton, OH 44711
Contact: Todd Hawkins, (800) 321-0699

Span: 11/99 to present

Goals: 1) Develop a method to specify, evaluate and control the installation of soil that is stabilized with a variety of agents.
2) Develop a method to customize stabilization solutions.

Projects: Data for the development of the field method will be generated in part during construction in early 2000. A laboratory method is to be developed that will monitor cure rates, ultimate modulus and index values for field installations to be determined for custom solutions.

Companions: Density, Moisture content & CBR.

Results: Work to date has shown that the GeoGauge is capable of enabling the goals.

Site: **California Polytechnic Institute**
San Luis Obispo, CA 93405
Contact: Brian McMinn, (805) 786-0164

Span: 9/98 to 6/99

Goals: Demonstrate a possible non-nuclear means of controlling compaction.

Projects: Comparison of measured density to the density estimated from GeoGauge and moisture content measurements at several institute and Caltran sites.

Companions: Density & Moisture content.

Results: All of the data was used by Humboldt to validate an analytical-empirical relationship between stiffness, density and moisture content. Sufficient correlation between measured density and density estimated from stiffness and moisture content that the estimated density was judged an alternative method for controlling compaction. This method was judged to be viable when a field instrument for measuring moisture content, as quick and simple as the GeoGauge, is available.

Site: **University of Massachusetts**
Amherst, MA
Contact: Dr. Al Lutenegger, 413-545-2872

Span: 8/99 to present

Goals: Develop a simple test for evaluating the strength of footings.

Projects: Comparisons of GeoGauge measurements to more conventional laboratory methods in an 8' x 8' test pit. The work is being funded by the FHWA.

Companions: Density, Moisture content & laboratory strength tests.

Results: None communicated to Humboldt as yet.

Site: **International Center for Aggregate Research (ICAR)**
Texas A&M University, Texas Transportation Institute
College Station, TX 77843
Contact: Alex Adu-Osei, 409-845-9291 or Dr. Dallas Little, 409-845-9847

Span: 12/99 to present

Goals: Validate mechanistic-empirical design model for unbound aggregate bases

Projects: Measurements of modulus on highway test sections constructed per design model predictions. The GeoGauge will be used to determine if the design modulus for the bases is being achieved in the field, rapidly characterize the uniformity of base performance and quantify if not control the effects of the construction process on the performance of test sections.

Companions: Density, Moisture content & resilient modulus.

Results: None communicated to Humboldt as yet.

Site: **University of Texas-Austin**
Austin, TX 78712
Contact: Kevin Folliard, (512) 232-3591

Span: 12/99 to present

Goals: Standardize the design, specification, testing and construction methods using Controlled Low Strength Materials (CLSM)

Projects: NCHRP Project #24-12, Controlled Low-Strength Material For Backfill, Utility Bedding, Void Fill, and Bridge Approaches The GeoGauge will used in the laboratory and in the field as one of the methods used to achieve the goals.

Companions: Density, Moisture content & resilient modulus.

Results: The laboratory characterization of CLSM is underway. No results have been communicated to Humboldt as yet.

Site: **NDI Engineering**
100 Grove Rd., Thorofare, NJ 08086
Contact: George Nagorny, (609) 848-0033

Span: 8/99 to present

Goals: Establish a simple, rapid method of establishing the quality of anchoring mobile arresting gear for military aviation application. He wants to evaluate the HSG to establish modulus requirements and inspect installations to those requirements.

Projects: The GeoGauge is being evaluated under contract to the US Navy and Marine Corp. as a means of establishing modulus requirements and inspecting installations to those requirements.

Companions: Density, Moisture content & DCP.

Results: Fieldwork to date shows the GeoGauge has the capability to enable the goals at shallow depths. An indoor test pit is under construction to characterize soils and installations using the GeoGauge under controlled conditions to validate the performance of NDI's design.

Site: **University of Wisconsin**
Madison, WI 53706
Contact: Dr. Tuncer Edil, (608) 262-3225

Span: 10/99 to present

Goals: 1) Have WisDOT adopt the GeoGauge in control of earth compaction.
2) Develop simple, rapid in-place & laboratory methods of evaluating the following:
a) Effectiveness of geosynthetics in stabilizing soft subgrades
b) Design procedures for cellular confinement systems in highways

c) Field performance of sub-bases constructed with industrial byproduct (e.g., foundary sand)
d) Soil stabilization and drying by use of fly ash
e) Equivalency of subgrade reinforcement methods

Projects: Several projects involving laboratory large-model studies in a test pit simulating subgrade and pavement systems and field demonstrations in actual highway construction. The usefulness of GeoGauge both in quality control and in providing direct performance values will be evaluated. Correlations with other methods of generating modulus will be made.

Companions: FWD & resilient modulus.

Results: Work is underway. No results have been communicated to Humboldt as yet.

Site: **CNA Consulting Engineers**
2800 University Ave. SE, Minneapolis, MN 55414
Contact: Chuck Nelson, (612) 379-8805

Span: 6/95 to present

Goals: Since there are numerous definitions of stiffness and modulus, physically quantify what the GeoGauge actually measures.

Projects: Measurements were made at various sites in Minnesota on various soils. A custom, quasi-static, automated field plate load test instrument was developed for comparison with GeoGauge measurements. Loading rates and loads were precisely controlled and automatically captured. The plate used was identical to the foot of the GeoGauge. **Note:** CNA has been involved with the GeoGauge since its early development. They have used it for everything from determining the uniformity of pipe bedding & backfill to detecting voids behind tunnel liners. They have more experience with the gauge than any other independent organization.

Companions: Quasi-static, automated field plate load tests.

Results: The GeoGauge measures the reaction of the soil to removing the working load. This was found to be relatively independent of any static loading.

Site: **SECOR International**
2321 Club Meridian Drive, Okemos, MI 48864
Contact: Roger Anderson, (517) 349-9499

Span: 10/99 to present

Goals: Develop the GeoGauge into an alternative to the nuclear gauge by using it to estimate density in companion with moisture measurements.

Projects: The gauge is currently being used on the backfill & bedding of sewer pipe installation. Next, it will be used on highway capping, lift by lift. A field

microwave oven is being used to measure moisture content. Analysis of the data won't be available for several months, until the end of the overall project. Once they become familiar with the gauge, they will begin to evaluate it for other purposes.

Companions: Density & moisture content.

Results: The gauge is reported to be working reliably and precisely. Quantitative results are not yet available.

Site: **Dixie Labs**
Mobile, AL 36670
Contact: Charles Chatham, (334) 479-5416

Span: 11/99 to present

Goal: Reduce premature building foundation and parking lot pavement failures by timely and comprehensive testing of compaction uniformity.

Projects: Several sites in the Mobile area where plumbers and electricians excavate prepared foundations and bases for their installations and exercise little care in their back filling. Sites where failures occur due to localized over compaction.

Companions: Density (sand cone & drive tube), moisture content (Speedy) & CBR.

Results: They will not use nuclear gauges and results to date show the GeoGauge as an alternative. They are gathering data to confirm the relationship between density, stiffness and moisture for themselves. They plan to correlate CBR data to the modulus derived from GeoGauge measurements.