“Evolving Geophysical Standards“

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ABSTRACT

What geophysical methods may be the most applicable to your project, and how are these individual methods applied? Five years ago, the answer was dependant on individuals and their experience. Today, geophysical standard guides are available to assist individuals, and provide answers to this question. This paper identifies current and pending ASTM Standard Guides, Provisional, and Standard Test Methods associated with surface geophysical methods. The paper discusses available standards, the rationale for developing the standards and the ASTM committee makeup. Finally, the new Standard Guide to Selecting Surface Geophysical Methods (D6429) is used to identify the geophysical techniques that are most appropriate for your next project.

INTRODUCTION - THE SCENARIO

You have been asked to work on a tunnel passing under a major topographic feature between two cities. Geophysics should be able to help identify changes in the rock strata where tunnel design or construction activities may require modification. Concerns may be caverns and voids (from mining or natural causes) or fractures and faults. These concerns can add significantly to time delays or the associated costs of addressing these unknown features. Not being a geophysicist, where would you turn for geophysical guidance? What do you ask for? How will you set a standard for the work that needs to be done? What is reasonable, and unreasonable?

THE PROBLEM

The scenario states a common problem, which has been historically resolved by reliance upon the experience or training of the engineer working on the problem. The success of geophysics for many geophysical investigations, applied to engineering problems, has been variable or not was has been anticipated. If an engineer has identified a geophysical method (right or wrong), defining the parameters for data collection, analysis and presentation has been a highly variable process. Some in the geophysical community have likened the normal request for geophysical bid as being similar to asking for an engineer to design a bridge, without identifying whether it is a railroad bridge, or farm bridge. Without identifying if the water body is a river or a stream. Without identifying the problem in a fashion that an engineer can design an effective bridge. After all, like geophysics, a bridge is just a bridge, or is it? From the prospective of the geophysical professionals, it was clear that some standards and awareness are necessary. But what standards are available? How were the standards developed? How can they be made effective?

THE METHOD FOR STANDARDS

There are many organizations that prepare and publish standards in the United States and the world. Most people recognize ASTM -The American Society of Testing and Materials. The ASTM was founded in 1898 by a group on engineers who recognized the need for standardizing the steel used in railroad rails. Today, the purpose of the ASTM remains similar the purpose of 100 years ago. That purpose is to develop voluntary, consensus standards for producers, users, ultimate consumers, and those having a general interest in a particular topic. Representatives of industry, government and academia meet in a common forum and write standards for materials, products, systems, and services. ASTM publishes more than 10,700 standards each year. These standards and other technical information are used throughout the world.

It is important to understand the nomenclature utilized by ASTM, and stated in this paper. The word ***standard*** as used by ASTM is a document that has been developed and established within the consensus principles of the ASTM and meets the approved requirements of ASTM procedures and regulations. When the word standard is used as a descriptor, such as in titles of test methods, specifications, and other documents, the word indicates consensus approval in accordance with ASTM procedures and regulations.

ASTM has various types of documents to provide a flexibility of form, communication, and usage for both the technical committees and the different users of ASTM documents. The type of ASTM document that is developed and titled is based on the technical content and the intended use, not on the degree of consensus achieved.

In 1990 there was only one surface geophysical standard available. This standard “Field Measurements of Soil Resistivity Using the Wenner Four-Electrode Method” (G-57). This standard, while good, was found by geophysicists to have technical flaws. The principal flaw was in determining the depth of exploration for the method. Clearly, there was a need to correct technical errors, and to expand on the number and type of geophysical standards available.

THE SOLUTION

Back in 1986 practicing geophysicists began to get heavily involved with the development of geophysical standards. Some of the active participants included Dick Benson of Technos, Frank Snelgrove of Geonics, Vince Murphy of Weston Geophysics, F. Pete Haeni of the USGS, Susan Solyanias of Mitretek Systems, Mark Vendl of the USEPA, Gary Olhoeft of the Colorado School of Mines and Wayne Saunders of SAIC among others. These people worked under the jurisdiction of ASTM Committee D18 on Soil and Rock, subcommittee D18.01 on Surface and Subsurface Characteristics and Task Group D18.01.01 Surface and Borehole Geophysical Methods (now named “Geophysics”). They began to consider guides for selecting surface and borehole geophysical methods. These individuals can consist of producers, users, and those having a general interest (representatives of government and academia), as well as consumers. With time, a consensus for new geophysical standards evolved, and new ASTM standards began to take shape.

The process of standard guide development is shown on Table 1. This process includes developing a consensus, writing a draft standard, securing subcommittee, committee and Society approvals. . This results in a standard being approved in a variety of forms, one of which is a Standard Guide. If it determined that a standard is needed in an expedited manner, only the approval of the main committee is need and a Provisional Standard can be adopted, and is good for only a two-year period. After this time, the provisional guide must be adopted in accordance to the rules of the society. In order to remain a “Standard Guide” all standards are subject to Society Member ballot approval every five years.

Another type of standard is the development of “Standard Test Methods”. The Test methods describe a specific technique (standard method) as it applies to a specific problem. The only geophysics specific standard test method currently available is for crosshole seismic testing (D4428/D 4428/M). This method was developed for the limited purpose of determining the horizontal propagation of compression and shear seismic waves at a test site when high quality data must be obtained. No other geophysical standard test method has been developed. However, some consideration has been given to other geophysical test methods in the future for applications such as UXO detection.

Table 1

ASTM PROCESS

Level	To Initiate	To complete Successfully and Proceed to Next Level
TASK GROUP (D18.01.01)	No formal requirements	No formal requirements
SUBCOMMITTEE BALLOT (D18.01)	• Subcommittee Chairman approval or motion passed at subcommittee meeting, • At least 30 days between issue and closing date, • Cover letter explaining reasons for ballot.	• 60% of ballots returned, • 2/3 affirmative votes (of total affirmative & negative votes cast on each item), • All negative votes considered, • No negative votes are persuasive or related.
MAIN COMMITTEE BALLOT (D18)	• Completed submittal form sent to HQ's with item, • All main committee ballots issued by HQ's.	• 60% of ballots returned, • 90% affirmative vote (of total affirmative & negative votes cast on each item), • All negative votes considered, • All Pink Forms completed and returned to Staff, • No negative votes are persuasive.
SOCIETY REVIEW	• Staff submits items to Society ballot after successful main committee ballot.	• All negative votes considered, • No negative votes are persuasive or related.
COMMITTEE ON STANDARDS (COS) REVIEW	• Staff submits item to Committee on Standards after successful Society Review.	• Committee on Standards agrees that correct procedures were followed. Note: Technical content is not reviewed by COS

THE SURFACE GEOPHYSICAL "COVERING" STANDARD

The first question that is commonly asked of a geophysicist is "What method should I select?" The answer has been changing for the last few years. Before 1998, the answer depended to a degree upon who was asked. The "Provisional Guide for Selecting Surface Geophysical Methods" (PS 78-97) was the first consensus-based standard answer to this question, when it was approved on May 27, 1998. Today, this provisional guide has been accepted as a Standard Guide (D6429-99), and been published by the ASTM.

D6429-99 identifies and describes twelve (12) different geophysical methods that are commonly applied to geologic geotechnical, hydrological and environmental investigations, as well as forensic and archaeological applications (Table 2). Each of the twelve methods is described in terms of applications, depths of measurement, ease of use, resolution, limitations, and references are provided. The methods included are:

Table 2
Geophysical Methods discussed in D6429

Seismic Refraction
Seismic Reflection
D.C. Resistivity
Induced Polarization (IP) or Complex resistivity
Spontaneous Potential (SP)
Frequency Domain Electromagnetics (EM)
Time Domain Electromagnetics (TDEM)
Very Low Frequency (VLF) electromagnetics
Metal Detectors and Pipe/Cable Locators
Ground Penetrating Radar (GPR)
Magnetics, and
Gravity

The guide identifies a variety of setting and geophysical requirements that must be present for the successful application of these methods. Insight into which common geophysical technique should be considered to be a primary choice of method and which may be alternate method for common applications is provided. General applications include geophysical investigations of

1. Natural Geologic and Hydrologic Conditions,
2. Inorganic Contaminants,
3. Organic Contaminants,
4. Man Made Buried Objects.

IMPLEMENTATION

Now that the common geophysical method can be identified with a reasonable degree of confidence by a non-geophysicist, the question of “What do I ask for?” remains. Addressing this issue, task group D18.01.02 has begun developing the specific standards for each of the common methods (Table 3).

Table 3
Standard Guide Development Status

Method	Standard Guide Status
Seismic Refraction	D5777-95
Seismic Reflection	Being Drafted
D.C. Resistivity	D6431-99
Induced Polarization (IP) or Complex resistivity	
Spontaneous Potential (SP)	
Frequency Domain Electromagnetics (EM)	Balloting Being Tabulated
Time Domain Electromagnetics (TDEM)	Being Drafted
Very Low Frequency (VLF) electromagnetics	
Metal Detectors and Pipe/Cable Locators	
Ground Penetrating Radar (GPR)	D6432-99
Magnetics,	
Gravity	D6430-99

Each standard guide follows a common format which includes a scope (including description of limitations, precautions), references, definitions, a summary of the practice, significance and use (including concepts, parameters measured and representative values, equipment, limitations and interference's), procedures including qualifications of personnel, planning, survey design, survey implementation, interpretation, quality control, calibration and standardization, report contents, method accuracy, precision and resolution and references.

SOLVING THE PROBLEM

These geophysical standard guides can be used to solve the tunnel problem that was identified earlier. Many of the potential problems associated with tunnel design and construction (which geophysics can help with) are related to natural geologic and hydrologic conditions. Primary choices for examining the depth, thickness, extent and continuity of consolidated and unconsolidated strata at a tunnel site include seismic refraction, D.C. resistivity, time domain electromagnetic and radar methods. Alternate methods include seismic reflection, frequency domain and VLF electromagnetic methods. Three of the four primary methods have new standard guides available. Examination of D6429 will provide insight into each of the methods, the applicability and limitations.

The geophysical standard guide is able to assist the user in identifying the geophysical methods that are recommended and those methods that are not recommended for a particular application. There is a short description of the applications, depth of investigation, ease of use, resolution and limitation of each of the methods used. Standard D6429 also includes a list of references for further evaluation of the applicability of a method for solving the project problem at hand.

CONCLUSIONS

Geophysics will play an increasing role in future civil engineering projects. The historical interaction between engineers and geophysicists has had both high and low points. As we enter the new millennium, geophysical standard guides are being developed to assist engineers and other professionals utilize geophysical methods in a technically sound fashion. Through the continued efforts of people involved with the ASTM, standard guides have been, and are being developed that will provide a basis for the use of geophysics.

About the Authors

Mr. Hoover has over 22 years geophysical background, and is currently employed by Science Applications International Corporation. Mr. Hoovers' experience ranges from environmental and engineering applications to near surface problems, exploration for oil and gas production, to research and development for a major oil company. Technical responsibilities have included all aspects of the geophysical industry, ranging from data acquisition, processing, data interpretation, and reporting. Surface Geophysical experience includes seismic reflection and refraction, resistivity, electrical imaging (EI) electromagnetic (including EM-31, EM-34, EM-61 and VLF), magnetometer and gradiometer, gravity, ground penetrating radar (GPR) and a variety of utility locating tools. Borehole geophysical experience includes the use of resistance, resistivity, SP, gamma, neutron, caliper, temperature, sonic, density, dipmeter, and televiewer data and equipment. Mr. Hoover is a licensed professional geologist in Pennsylvania, a member of American Geophysical Union, American Institute of Professional Geologists, American Society of Civil Engineers, European Association of Exploration Geophysicists, Environmental and Engineering Geophysical Society and the Society of Exploration Geophysicists

Mr. Saunders is currently chairman of the ASTM sub-committee D18.01 on Surface and Subsurface Characterization, which includes the task group D18.01.02, Geophysics, which is responsible for the development of surface and borehole geophysical standards. Mr. Saunders has over 25 years of experience in the application of both borehole and surface geophysical methods to a wide variety of applications, including, environmental, geotechnical and engineering. Mr. Saunders serves as a Senior Geophysicist with SAIC and his current assignments are dealing with geophysical applications to the detection and discrimination of unexploded ordnance (UXO). In addition, Mr. Saunders continues to apply geophysical methods in "urban environments" for a wide variety of geotechnical projects, including major airports and construction sites.