From Geo-Innovation to Geo-Implementation

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"Genius is one percent inspiration and ninety-nine percent perspiration." —Thomas A. Edison

It is difficult not to feel a bit overwhelmed by all of the innovations in information technology, as cell phones compete for our attention with I-pods, the internet, computers and television. However, we should keep in mind that key innovations also have occurred and are occurring within our own field of geotechnology. The main problem preventing a wider recognition is that our changes are not always obvious; on the contrary, they may, in effect, be only a passing moment, to then be forever covered and concealed underneath the ground surface. Here are a few examples:

- Needing better site investigation tools, the Dutch invented the Cone Penetrometer, the French invented the Pressuremeter, and Iowa invented the Borehole Shear Test. And, we must not fail to mention the Ground Penetrating Radar, crosshole geophysics, and the Surface Analysis of Spectral Waves (SASW) method developed by Ken Stokoe at the University of Texas;
- For deep foundations, slurry methods were developed to keep drilled shafts open, the people at Intrusion Prepakt conceived auger-cast piles, and the Wave Equation Analysis method was developed to predict the capacities of driven piles, providing some significant advantages over the old Engineering News formula; and
- With regard to soil improvement, the Germans figured out how to insert a vibrating probe in the ground and called it vibroflotation, and a plethora of grouting methods, such as compaction grouting, chemical grouting, and jet grouting, among others, were developed to increase shear strength and reduce compressibility and permeability.

Figure 1. Rammed Aggregate Pier™ Foundation System. Photo courtesy of Geopier Foundation Company.

Geo-innovations are not just history, as they continue to occur as our profession grows. Recent years have seen development and implementation of slurry walls, mechanically stabilized earth (MSE) walls using internal reinforcement, soil mixing *in situ*, and Geopier® Rammed Aggregate Pier™ foundations. We have also seen the use of geosynthetics for separation and erosion control, and emerging intelligent compaction devices.

Seven Primary Factors

What gives life to some geo-inventions and not to others? We suggest seven primary factors in the successful implementation of nearly every geo-invention.

1. It Takes A Good Idea, But Not A Brilliant One

Not all good ideas make it—but the ideas that do seem to share one common attribute: They are simple in principle. The greatest geo-inventions are the ones that either answer a simple question or are, by nature, simple themselves.

- Q—Wouldn't it be great if we could relieve excess pore water pressures by reducing the seepage path length?
A—Wick drains

- Q—Wouldn't it be powerful if we could add a tensile element to the soil to reinforce for tensile stresses?
A—Structural geogrids

- Q—Imagine if we could solve problems with complicated boundary conditions simply by dividing the great big picture into many little ones and then imposing continuity across the boundaries.
A—Finite element modeling

Figure 2. Mechanically Stabilized Earth (MSE) walls. Photo courtesy of The Tensar Corporation.

The best innovations evoke the response: "Why didn't I think of that?"

2. Perseverance In The Face Of Criticism

Inventors must be patient and prepared to weather criticism. Most people, even engineers, tend to think ahead by looking backward, like a surveyor laying out a straight line. An idea that is truly innovative and rocks the boat can quickly become drowned in a sea of criticism and naysaying. Without a staunch advocate, or "champion," even the most brilliant innovations and inventions may not stand a chance.

The successful geo-inventions require vision, passion, and commitment during both good times and bad. The Wave Equation Analysis method, now uniformly accepted as state-of-the-practice, was subjected to unrelenting criticism, but was steadfastly defended by George Goble and others. Mechanically stabilized earth walls were once considered by many as useful as "pulling yourself up by your bootstraps" but are now universally accepted, in large part due to the advocacy of Henri Vidal for Reinforced Earth. During the early days of Geopier Foundation Company, some geo-professionals pointedly called the system "voodoo." Without the thick skin, patient perseverance and commitment of Dr. Nathaniel Fox and others, this technology would not be the mainstream tool that it is today.

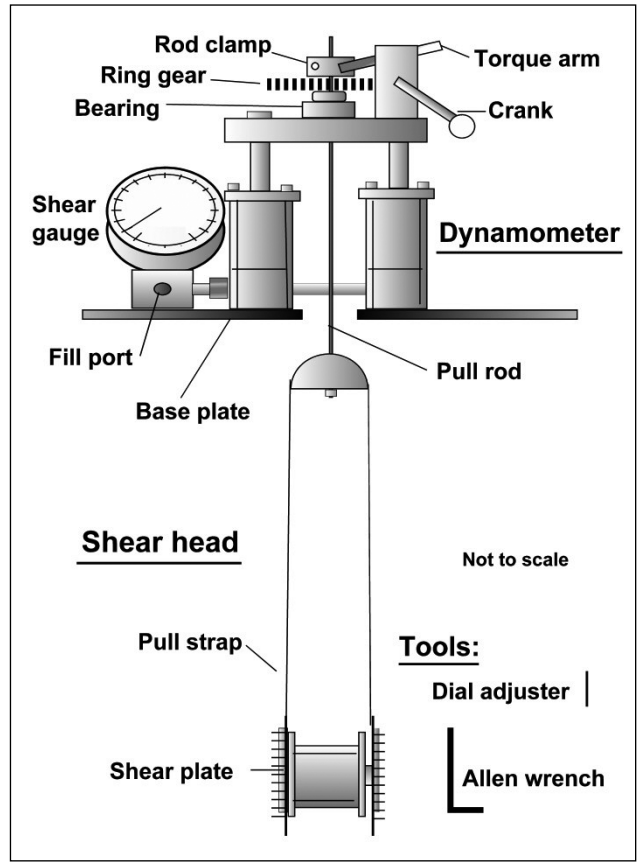

Figure 3. Borehole Shear Test Schematic.

A one-size-fits-all mindset does not work well in our profession in general and works even less well for new approaches.

3. Listen To The Underground

Commitment is not the same as blind commitment, and despite the euphoria, no invention is "perfect." No technology is without limitations that, if not recognized and heeded, can become an ugly blemish on development. A few overly enthusiastic practitioners tried to extend MSE wall construction to include cohesive soils, with predictable consequences. Heavy tamping (dynamic compaction), effective in granular soils, meets its match in cohesive materials, where tamping and excess moisture can cause remolding and heave instead of compaction. Each breakthrough technology has limitations that may or may not be readily apparent to the inventor and designer. Thus, every step of the process, from idea to invention, must be coupled with continuous geotechnical measurements and observations. Only then can the strengths and weaknesses of an invention be objectively evaluated.

4. Keep An Eye Towards Soil Mechanics

In the heat of invention, we sometimes forget about the simple laws of soil mechanics that got us here. Compressive stresses, shear stresses, load transfer, seepage, and compressibility all drive the behavior of geo-media, with or without new inventions. For example, numerical solutions, which seemingly address "any" problem efficiently, are only as good as the constitutive models, boundary conditions, and loading sequences applied by the modeler. Lest we forget, soil mechanics that were developed during the era of the slide rule still work! Adaptations of classical soil mechanics are often the most successful path towards explaining strengths and limitations of new adaptations inventions.

As inventors, we must keep in mind that while we may have designed a new product, created a new theory, or even changed the way we view a problem, we have not changed, nor will we change, the fundamental principles of nature or the intricacies of soil mechanics. We have simply changed the way we react and adapt to them.

5. Surround Yourself With Good People

The success of an invention is not possible without field professionals who are willing to "take the leap" with a new technology. The invention's implementation and usage results in a cycle involving feedback that affects design recommendations and improvements. Can you imagine what the geosynthetic industry would be without the steady guiding hand of Bob Koerner? How about the specialty products encapsulated in geo-instrumentation—where we would be without the direct yet critical eye of John Dunnicliff?

Geo-innovations are championed by a few visionaries and implemented by the many solid people who are willing to focus and draw attention to the new technology.

6. One Size Does Not Fit All

Geo-innovations must be carefully applied to each project, and the special geotechnical characteristics and circumstances of that project must be brought to bear. New technologies require continuous validation, especially in the early introductory phase. By applying the lessons learned on these projects, we are able to hone the technology for future uses. A one-size-fits-all mindset does not work well in our profession in general and works even less well for new approaches. Thus, while it may be tempting to idealize one's new invention as a cure-all, disappointing results will often be the outcome of such a characterization, and may even diminish the overall perception of the invention.

7. Passion And Protection

New inventions and innovations must be closely guarded, both in respect to their patent and also to their correct usage and application. Imagine what may have happened to the MSE wall industry if less-than-skilled practitioners took liberties with design methods that may have led to projects with poor performance and failures. Passionate and successful geo-inventors protect their technologies and methods by setting strict and stringent usage guidelines and by limiting the number of people who practice the technology.

Figure 4. Jet grouting. Photo courtesy of Earth Tech.

In the late 1980's, the Tensar Corporation developed semi-empirical design software, validated by field instru-

mentation results, that allowed users to analyze reinforced slopes and walls, yet guarded against poor designs. These protections are good not only for the geo-inventor, but also for the industry as a whole, because they allow for the implementation of innovations while guarding against failures—to the betterment of the construction industry and to the advantage of the project owners.

Conclusions

Though not well known in popular culture, our profession has a rich history of creative innovation and invention.

• The best improvements tend to be those that are simple in nature and are implemented by champions who have the courage to stand up to criticism, both justified and not.

• Successful geo-inventions are thoroughly tested and are designed using methods that follow the basic tenets of classical soil mechanics.

• No system is implemented without good people who passionately address the needs of each project uniquely and whose inventors guard their innovations against misuse by those less knowledgeable.

Seems simple, doesn't it? The notion that successful geo-innovations can be reduced to seven straightforward key factors may appear a bit frivolous, but often, things are less complicated than they appear. This is not to minimize the dedication, tirelessness, or inherent brilliance that also must accompany any successful geo-invention. However, with many innovations and inventions that fall by the wayside every year, often to the detriment of our profession, it is our goal that these seven principles provide a tangible framework for budding inventors. There is always room for growth and improvement. It is to the benefit of all of us that these geo-inventions have at least a fighting chance. ❍

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