// Lessons Learned from GeoLegends

Gonzalo Castro, PhD, PE, NAE, F.ASCE

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Dr. Gonzalo Castro

Gonzalo Castro is an internationally recognized expert in soil dynamics, vibrations due to blasting and machine foundations, earthquake engineering, and liquefaction.

Born in Chile, Castro received a bachelor of civil engineering degree from the Catholic University of Chile in 1961, and a master of science in engineering degree from George Washington University in 1965. He earned his PhD in engineering at Harvard University in 1969 with a thesis on liquefaction of sand. While studying at Harvard, he had the opportunity to perform research with Arthur Casagrande, a pioneer in the area of earthfill dam design. Shortly afterward, Castro joined Geotechnical Engineers, Inc. (now GEI Consultants, Inc.), which had just been launched by Drs. Ron Hirschfield, Steve Poulos, Daniel LaGatta, and Richard Murdock. He currently serves as a senior principal with the firm.

During his 46-year career with GEI Consultants, Castro has provided consultant services for over 20 nuclear power plant foundations and for the earthquake stability of numerous dams in the U.S. and abroad. He has received three National Science Foundation (NSF) grants for researching soil behavior under seismic loading. He has also given lectures and published numerous papers on the same subject. In 2003, Castro was elected to the prestigious National Academy of Engineering (NAE) for his contributions to geotechnical earthquake engineering, soil dynamics, and the seismic safety of dams.

Q: How did you first discover your interest in geotechnical engineering?

While at the Catholic University of Chile, I worked in the school's soil mechanics laboratory performing testing for outside geotechnical consultants. Then, during my last year there, a series of earthquakes hit Chile in May of 1960.

These events were historically some of the largest earthquakes anywhere, with the strongest event having a magnitude of 9.5. I witnessed a tremendous amount of damage while traveling with my professors to the affected area about 10 days after the event. The amount of destruction was devastating, with much of it geotechnically related, and often caused by liquefaction. After travelling through different towns, we got to one where nothing stood, absolutely nothing. We learned later there had been soil amplification at that locale. Back then, I had no understanding of this phenomena, but knew that something strange was going on. As many as 5,000-6,000 people died, many from the tsunamis that followed the earthquake. Observing this was a life-changing experience that led me to a lifelong interest in geotechnical engineering.

Castro (seated on the left) plans subsurface exploration for sand column densification in Southern Taiwan in the 1970s.

The GEI founders, circa the 1990s. Upper Row: Dick Murdock, Steve Poulos. Bottom Row: Ron Hirschfeld, Dan LaGatta, Gonzalo Castro.

Q: Since receiving your bachelor's degree, which phase of your life was most stressful, and how did you overcome that?

My time at Harvard provided tremendous rewards, and many good things happened to me, but at the same time it was very stressful. I was married and had three little kids. Whenever you're doing research, no matter how much you enjoy it, you want to be done with it. But at the same time, you want to give attention to your family, so it's a struggle.

My PhD program was lengthy. I started my thesis in late 1965, and finished it by the end of 1968. Interestingly, there's a funny story about that. Casagrande had a special program for practicing engineers during the spring semester where he would invite famous people to lecture. One regular visitor was Harry Seed, who was involved with liquefaction studies at Berkeley. After the lectures, Casagrande would invite his doctoral students to tell the visitors what we were working on. It turns out that Seed and Casagrande had different opinions about liquefaction. I explained what I was doing, and then, of course, Casagrande and Seed started arguing about things. I stayed very quiet! After Professor Seed left, Casagrande called me to his office and told me he had developed ideas for additional work for me to do. As a result, the scope of my work always increased with these yearly events.

So how did I survive this stressful period of time? I must say that the key was the strong support of my wife, who somehow managed to care for and feed our three kids, and me, without much money. I could never have done it without her.

Al Azhar Park in Cairo, Egypt.

Dynamic compaction of foundation soils for Steel Creek Dam at the Savannah River Plant, SC.

Q: What has it been like being the principal of a large, well-known firm?

While very rewarding, it could be stressful. I had the fortune of being a principal of the firm with four great partners. The five of us stayed together until we all retired. That's a bit unusual. Over the years, many have asked, "How do you guys stay together?" and "Don't you fight once in a while?" We certainly had different interests and capabilities, but we complemented each other very well, and we respected each other. That was the key, I think. We reached many decisions, some important and some not so important, but we always tried to reach a consensus, and we all stood behind the joint decisions, whether we had personally supported them or not. And most of all, we moved forward without looking back and saying 'I told you so' to the ones we disagreed with.

Q: Who most influenced your career and why?

Several individuals were important in my career. However, Steve Poulos, who became my partner at GEI, was the most important person. When he was an assistant professor at Harvard, he was very supportive in helping me with my thesis work. He's the one who encouraged me to join the other four founders of GEI. Then, at GEI, he was the person with whom I probably worked the closest because of our common interests.

Q: What's the most memorable project you worked on during your career?

There are two, but for different reasons. One was technically demanding and stressful; the other was just a lot of fun! The demanding project was an earth dam in South Carolina. The site for the dam had some of the loosest sands I've ever encountered, and liquefaction was a problem. The loose sands had a small quantity of clay (3 to 5 percent), so we thought it would behave like a sand. But when we tried to densify it, we realized that wasn't the case. We found that the liquid limit of the minus 200 sieve fraction ranged between 200 to

300 percent, so it probably had some montmorillonite in it. We recommended densification by dynamic compaction and stone columns. When the necessary compaction couldn't be achieved quickly enough, we conducted QC testing. Eventually we got the sands densified, but to get there required lots of overnight testing, engineering assessments, and countless meetings. I traveled to the site every week for a long time. This project was definitely one of the more demanding and stressful I ever worked on.

The fun project was located in Cairo, Egypt. The project was fun because the geotechnical issues were different from all other projects I've worked on. It involved a hill just outside an old city wall that was about 100 ft high. The hill had evolved over the centuries because it was the place where unwanted materials were dumped. Geotechnically, the hill consisted of silty, gravelly sands. GEI was retained to help with the design of a park on top of the hill. When I first got to the site, I noticed that one of the construction trailers had an area where the trailer was supported on several rows of bricks. I thought "that's strange," and then I noticed that plants were growing in the same area. I suspected that irrigation watering caused the ground to settle, and realized that settlement would be a problem for the planned development of the park, which included restaurants, meeting places, and water fountains. I also learned that a tank and piping system built on the hill had leaked during recent water testing. The infiltrating water led to significant settlements even though the tanks and the pipes were supported on piles, so downdrag on planned pile-supported structures would be a serious problem. The solution was to place a clay cap layer on top of the entire hill so that water from irrigation would not infiltrate into the hill. I visited the site regularly for about 10 years. The final product was beautiful.

Q: What lesson did you learn from a project that didn't go as expected?

The project involved an excavation in very soft ground. Ground freezing was selected to support the excavation. Unfortunately, ground freezing was done too close to an existing home that we didn't realize was there, so the home was damaged by settlements when the ground thawed. The finger-pointing was bad, and the business with lawyers afterward became very complicated. But my key point is that I believe I could have prevented these problems if I had devoted more time to the project. I learned my lesson that one always needs to spend enough time, ask enough questions, and visit the sites more often. This happened early in my career in the 1970s, and I've not forgotten it.

Q: Do today's engineers depend too much on technology?

I don't think so. I think technology has allowed big changes to take place in how we practice, even in the little things like organizing data with Excel. For the reports that I prepared back in the 1970s, I would write a rough draft, and I'd give it to typists who would do what they could to understand my poor handwriting. Then, when I reviewed it, I would make changes, and the report would need to be retyped. It was an agonizing process to produce a decent report! The efficiency that we have now represents an enormous improvement.

Castro with his wife Nora at the ceremony inducting him into the National Academy of Engineers in 2003.

There have been important technology improvements on field instrumentation and remote sensing. They don't provide *all* the answers, but they provide *important* answers that we couldn't get before.

The currently available analytical procedures to analyze stresses, strains, and displacements, with soil models that are being continuously improved, provide valuable insight into what's going on inside a soil mass.

As a geotechnical engineer, however, your responsibility is to make sure that we don't accept at face value what technology tells us, for example from a complicated finite element analysis. If you blindly accept the results of such analyses, you're abusing technology. Start with the simplest analysis to get an idea of the order of magnitude of the key parameters and to identify the key issues, so that your model addresses the issues that are in question.

As analytical tools become more complex, the tendency has become — and it's kind of unavoidable — that there are people who are very good at doing analytical work, but they may not have the opportunity to touch a piece of soil and get their fingers dirty. If you become strictly an analytical person, your participation must be balanced with people who don't have that skill, but have a good understanding of

Castro with the authors Corey Snider and Amanda Parry.

soil mechanics principles. It requires a team effort — and this is more so today than many years ago, when most practitioners could, and would, do everything. As practitioners become more specialized, it becomes more important to have a balanced team to address the various issues that arise on geotechnical projects.

Q: What do you see for the future of geotechnical engineering?

I see a good future. There are very good people entering the practice. There's a lot we have to look forward to. I think that in the consulting world, the competition is hard because there are many good firms, all around the country.

At GEI, we've shied away from clients and markets that are price-competitive because they will cause the quality of practice to diminish. It's unavoidable, however, that some clients will believe that the cheaper service they get, the better off they are. Educating our clients about the importance of the quality and continuity of the services we provide is, and will remain, an important challenge in the future of geotechnical engineering.

Q: What advice do you have for young geotechnical engineers just entering the field?

As you begin your career, you should, as much as practical, be proactive about the path you take. So in this regard, I suggest that you not specialize in any specific part of the practice. Sometimes you may not have much input about this because you may be assigned to work on a specific type of project. Regularly talk to your supervisors to express your interest in working on different types of assignments.

I also recommend you ask questions of others, even if you think you know the subject. I've always told our engineers that asking questions is not a sign of weakness; rather it's a sign of strength. Feel confident that asking questions will not be held against you.

Q: What are the top three qualities of a successful engineer?

First, be humble about what you know — and what you don't know — as I've already discussed.

Second, be a good observer. When you go to a site, try to notice things that you weren't expecting to see or had not been looking for. Make sure that you document it, think about it, and internalize it. For example, at a dam you may be looking for the obvious things, like water shooting out of the dam, but then you may see something that initially seems insignificant. Don't simply disregard it. Make a note of it, so that later it may become clear to you whether it is significant or not. Being a good observer means not to have predetermined ideas as to what you expect to see.

Third — and this may seem to be counter to the quality of being humble — be skeptical. Every time you get a piece of information from an analysis, from field measurements, or from other sources, you must be skeptical about the information. Is the information right or not? Does the information make sense? Always corroborate any data because geotechnical data, regardless of whether the results are from laboratory or field tests, or performance monitoring, can have a very significant range of potential error. GS

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