# Building on solid foundations

PES was delighted to learn from geotechnical engineer Thomas Berglin at FTC, about the importance of foundation design for solar projects. After all, without a solid foundation, the grandest structures imaginable will not stand the test of time, much less a simple solar rack.

**PES: Thomas it is a pleasure having you with us. Would you like to begin by giving our readers a brief overview of who you are and your background?**

**Thomas Berglin:** Thank you, it's a pleasure to be here. I grew up in a large family in North Pole, Alaska and graduated from the University of Alaska, Fairbanks in 1998. One of my passions is frozen ground, or permafrost engineering. I own drilling equipment and have practiced foundation engineering around the world in many climates and in many cultures.

**PES: How long have you been in the solar industry?**

**TB:** I left international heavy mining, mostly open pit for precious metals, to join the solar industry in 2015.

**PES: What would you say are the most challenging aspects of a solar project?**

**TB:** Let me first share what I find to be the most enjoyable aspects of solar projects. The most enjoyable aspect to me is taking complex technical information and helping people from all backgrounds to understand it in familiar terms.

Now, the most challenging aspect of the solar industry, at least for me, is balancing economy and stability with limited information and limited time in a very competitive market. Related to that is applying oversimplified and highly conservative building structural codes to the design and construction of solar trackers.

**PES: How important is foundation design?**

**TB:** When people ask me questions about the importance of foundation design, I usually cite something out of the New Testament according to a guy then called Levi. He would later be called Matthew. Paraphrased, it says 'the wise person builds on stable ground and the foolish person builds on unstable ground.'

In my opinion, in each case, the ground isn't the problem. Ignorance of ground conditions is the problem. So, knowing ground conditions going in is extremely important.

**PES: What are the basic guidelines for designing foundations?**

**TB:** Knowing ground conditions is the starting point. From there, foundations must be designed and constructed to resist the loads imposed on them by mother nature, without overstressing the materials out of which they are made, e.g. steel and concrete and the materials upon which they are founded, e.g. earth and rock.

**PES: Would you say that the solar and PV industry is changing?**

TB: Oh yes, very much. The ground mount solar industry had very humble beginnings. Some early ground mount solar panel foundations were little more than glorified fence posts that had precious little engineering involved.

Since then, solar farms have grown from a few kilowatts to up to a gigawatt and larger, and modules have grown much larger along with them. Much more research and development is going into the design of solar trackers than ever before, including load testing, wind tunnel testing. Engineering scrutiny of design has increased along with the size and cost of the farms.

The solar industry is not only changing internally, it is also changing public perception about energy consumption and energy diversity, and helping the planet to become more energy conscious.

**PES: Can you tell us more about foundations?**

TB: Driven foundations for ground mount solar usually come in two basic configurations. A single-post, or monopost support, which is a post sticking up out of the ground, and a front-back configuration, which, as the name suggests, has two supports, one in front and one in back, like two legs supporting a half of a table. Both connect to the structural frame supporting the solar panel. Monopost foundations usually consist of driven wide-flange, 'W' sections, or 'I'-beams and sometimes steel channels, or 'C'-shaped sections, are used. Front/back are often also channels. Just smaller.

Helical piers, a long pipe with a circular plate bent into a helix and welded to the bottom, are also sometimes used as monoposts if they are stiff enough, usually 5+ inch diameter, where soils are especially weak, or uplift loads are large.

Where soil is deep and of sufficient strength, W-sections are driven directly into the ground. Where bedrock is shallow, a pilot bore that is slightly smaller than the hypotenuse in diagonal dimension, of the W-section, or channel, can be pre drilled into the rock with a rock drill, and the steel section can then be rammed into the undersized bore, think Sword in the Stone.

Front-back systems can also be supported by ground screws in soils that contain excessive cobbles and boulders, though pre drilling is usually required for ground screws as well as monoposts. Directly driven steel sections are by far the most common and least expensive of the options available.

**PES: What is load testing?**

TB: That's a great question, as there is some confusion in the solar industry about this subject. Load testing involves installing a number of test posts at various locations across a site of interest and then loading them axially, or vertically, and laterally, or horizontally, to impose the environmental loads that the tracker could feel during a design event.

Thomas Berglin

Load testing can be accomplished with a couple of basic aims. When a predesigned steel section with a predesigned height above grade and a predesigned embedment depth is installed at the site of interest and loaded to the ASCE 7 or other design loads to see if it can resist them, it is sometimes called a validation or a 'proof' test. This is effectively a full-scale load test in that the actual foundation that is tested is the same that will be used in construction.

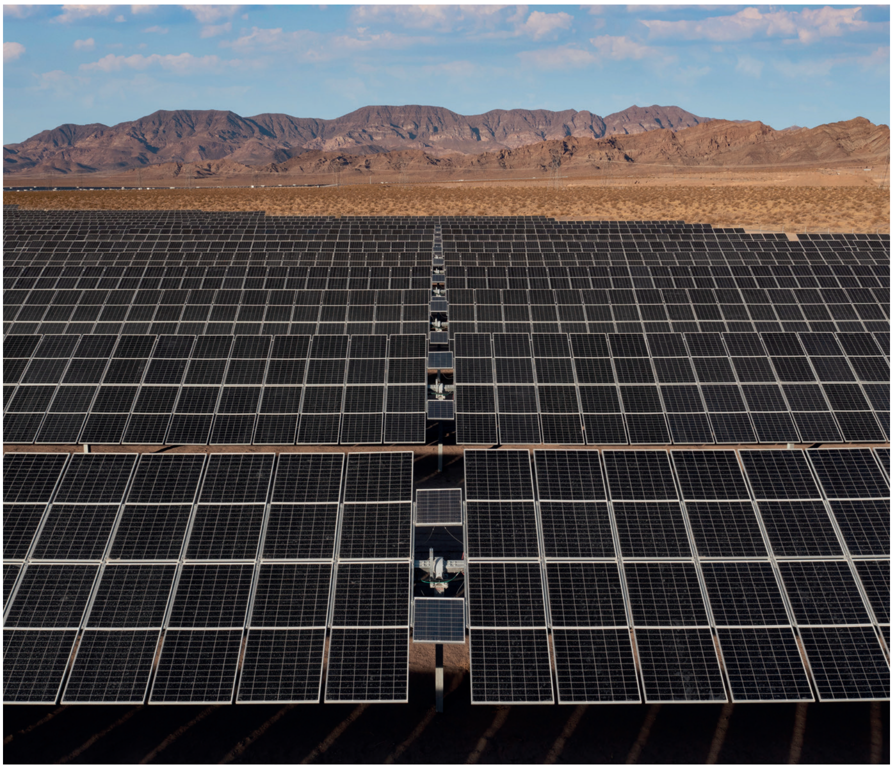
In contrast, performance testing is accomplished irrespective of the factored design loads and is used not to validate the capacity of a given predesigned post to resist a design load, but instead to measure how much load it takes to overload the soil. With the soil capacity known, a steel post can then be sized using appropriate safety factors to prevent soil overloading.

With this approach, the foundation can be optimized, usually resulting in a reduction of steel and commensurate cost savings. Put another way, if a proof test holds the design loads, it only tells you that the foundation you've estimated is adequate. It won't necessarily tell you that your section could have been shallower, or lighter.

**PES: Why is load testing important?**

**TB:** During early stages of project development, a geotechnical consultant is usually retained to go to a site and explore ground conditions. They'll use a drill or a backhoe to get samples of what's down there and to try to get at the strength of the subsurface materials using some form of standardized test, which can be related to information contained in the engineering math books.

Most commonly used in the western hemisphere is the Standard penetration test, so called, because a lot of engineers early on agreed it should be called standard. It involves hammering a length of steel pipe into the ground to get an idea of how strong it is. From these details, design information is derived using mathematical formulas developed over the years. This is called an analytical approach as it uses a combination of soil mechanics theory and engineering judgement, and depending on the level of experience of the engineer, it may get you all the way to a 90 per cent design.



However, most geoconsultants often tend to apply conservative safety factors to analytical designs. When load tests are available (either proof or performance) lower safety factors can be applied, resulting in a more economical design. Further, owners sometimes feel safer relying on load tests for their own peace of mind.

**PES: Can you explain how foundations work in different geographies? For example, is there a difference with how foundations are designed for North, South, East and West coasts?**

**TB:** Geology, climate, and geography each play an important role in driven foundation design. Climate is mainly responsible for driving forces. Examples of driving forces are wind loads, snow loads, seismic loads, and frost action loads. Geography, e.g., sloping terrain, can also contribute to driving forces. Geology and geologic processes affect the resisting forces.

Take a given soil, let's pick sand. Sand in a coastal setting or near a stream bank will usually, when loaded, behave very differently than the same sand which once had a half mile of ice parked on top of it for a few million years. Sand that is disturbed by moving water or wave action will be weaker. Sand that once had an ice sheet (or the lobe of an ice sheet) crushing it will be very dense and very strong. So back to your earlier question about the importance of foundations. Knowing the environment, geography, and the geology are critical to the design of stable foundations.

**PES: Does the size of the foundation affect the performance?**

**TB:** Foundation size does affect the performance. The larger the foundation, the less it deflects under a given horizontal, e.g. wind, seismic load. And the larger the section, the more surface area is available to resist axial load, through side friction or adhesion.

Because the size also impacts cost, it is extremely important to balance stability with economy. It's easy to oversize foundations to be safe. But in the solar industry, especially the utility scale solar industry where you might have 40,000 foundations, an extra foot or two of steel and an extra pound or two per foot of foundation or post length adds up very quickly.

**PES: Can you explain coating and how it affects the foundations, and life expectancy?**

**TB:** That's a great question. In solar, especially in the United States, coatings such as hot-dipped zinc are applied to driven steel foundations to help protect them from the effects of corrosion over time.

Zinc is lost to corrosion at a slower rate than plain carbon steel and that can add at least 7 to 10 years to the life expectancy of a driven post in corrosive environments. In the most corrosive environments, coatings may be nonmetal and may be a form of polymer or resin, but these can be sheared off during post installation, especially when posts are driven into dense sandy or gravelly soils. The standard zinc coating is at least 3 mils, or about 0.003 inches. Thicker coatings are possible but are difficult to reliably reproduce consistently. And thicker zinc coatings lead to other adverse impacts such as globs of zinc here and there which sometimes must be ground off to allow for racking assembly.

**PES: What are the benefits of load testing and why should all projects perform it?**

**TB:** Load testing is always beneficial in validating analytical designs, that is designs based mainly on math and soil mechanics theory. Depending on the level of experience and comfort of the designer, load tests may also result in reduced costs. If the designer is experienced, the load tests often show that the analytical design was adequate. In some cases, load tests may show that a longer or heavier foundation is required.

**PES: Does width affect the design?**

**TB:** The width of a wide flange section (e.g., an I-beam), is related to its available surface area, to resist vertical forces through side friction or adhesion and its stiffness, to resist horizontal bending forces. The flange is also what is pressing against the subsurface materials in front of it during loading. The wider it is, the more soil is pressing against it to resist it.

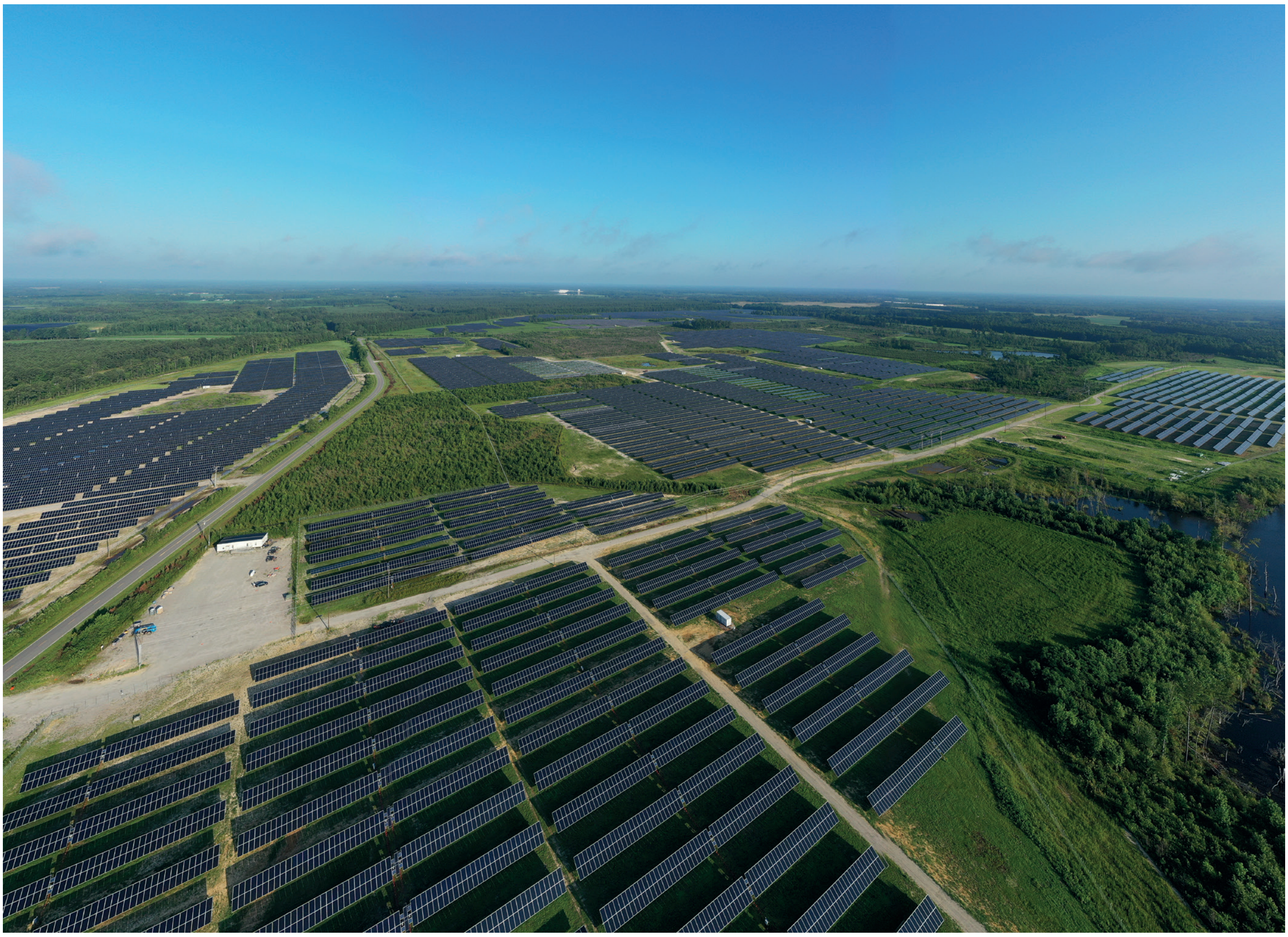
Think of it like a bulldozer blade. The wider the blade, the bigger the CAT required to push the earth in front of it. Most wide flange sections used in solar, e.g. W6x7, W6x8.5, W6x9, W6x12, W6x15, W6x20, W8x10, W8x13, W8x15, W8x18, W8x21, have comparable widths between about 4 and 6 inches and so it's more about the stiffness of the section, width, depth, and thickness, than it is about the width of the flange. But added width definitely helps.

**PES: Why should prospective clients choose our foundation and expertise, and what makes how you designed them different from competition?**

**TB:** FTC's in-house design team includes licensed, expert-level foundation designers whose experience helps them to maintain the balance between economy and stability and math and the theory. They also operate heavy equipment and have personally pulled on different steel sections in different geologies around the world. This balance of skillsets gives FTC designers a competitive advantage when it comes to optimizing foundation and structural design.

**PES: Customers are always asking for suppliers to be flexible. How does FTC provide flexibility in the foundation design?**

**TB:** FTC encourages a culture of flexibility, and this culture permeates everything we do. Many of our teammates work from home and we're able to maintain the work-life balance that allows us the freedom to be creative and expressive and to both work and to think outside of the box. During



predesign, FTC's experienced engineering team value engineers practical, down-to-earth foundation solutions that draw on decades of experience in every climate from the arctic to the tropics on both sides of the International Date Line.

During construction, it doesn't matter how vanilla a site appears to be, there are very nearly always issues that arise that require a thoughtful approach to reduce or minimize costly delays. During every stage of design and through to finished construction, we work very hard to stay ahead or keep pace with the project needs as they arise, to help the project succeed.

**PES: Do you have any personal thoughts about the solar and PV industry in general?**

TB: Sure I do. I feel that as global demand for energy continues to grow, a diversified energy industry is in everyone's best interest. Having all of your eggs in one basket always invites risk and to this rule, energy eggs are no exception. For this reason, I think most people expect solar to continue to evolve and to grow in the years to come, at a rate that is consistent with previous experience.

The current disruptions to commodities and to the global supply chain will eventually calm down, but the demand for energy will only continue to grow until it eventually outpaces supply. We need alternatives to fossil fuels. In the short term, renewables can certainly take some of the pressure off of more conventional energy supplies. In the long term, with continued perseverance, renewables may completely supplant other energy sources.

**PES: Are there any future innovative things coming out in regards to tracker foundations?**

TB: We are currently partnering with different EPCs to help them develop the capacity to install driven wide flange beam foundations where ground conditions are very hard, e.g. shallow bedrock or caliche, especially in the Desert Southwest. We start by pre drilling a pilot bore into the rock that is slightly undersized relative to the dimensions of the post. We then ram the wide flange section into the bore and that's that. Square peg, round hole.

I personally call it a rock socket; others probably have other names for it. The first one I did was in 2016 at a shallow rock site in the Pacific Northwest. It's effectively the same principle used to install ground screws, but it's a single rammed post instead of two turned screws. It is an alternative to a ground screw. We're also working on offering foundation solutions for areas where ground conditions are very soft, like coastal plain settings.

**PES: Is there anything you would like people to know or understand about solar foundations?**

TB: I guess I'd like to close with a philosophical statement about foundation engineering that comes from one of my old textbooks, Foundation Engineering by Peck, Hanson, and Thornburn ©1984 John Wiley and Sons. I feel it really sums up the plight of the foundation engineer.

'In reality, soil mechanics is only one of the bodies of knowledge from which the foundation engineer must draw. If studied to the exclusion of all other aspects of the art, it leads to the erroneous and dangerous impression that all problems in foundation engineering are susceptible of direct scientific solution. Unfortunately, the vagaries of nature and the demands of economy combine to eliminate this possibility.'

**PES: Thank you for joining us today.**

TB: My pleasure, thanks for having me.

The preceding/views/suggestions are those of Thomas Berglin P.E., and may not reflect views of FTC Solar.

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