How To Choose a Ground-Mount Solar Foundation That Lasts 40 Years Or More

Today's solar modules are producing more power for longer than ever before. But are the foundations they're mounted upon able to go the distance with them?

Just 25 years - today's standard warranty for most premium modules - might not be enough. A properly researched and installed foundation needs to last 40 years or longer to keep up with the modules installed overtop it.

That's because the recent NREL (National Renewable Energy Laboratory) paper *"Photovoltaic Degradation Rates - An Analytical Review"* determined that modules deteriorate at a median value of just 0.5% per year.

So solar modules and arrays can be expected to produce more than **88%** of their original rated power after 25 years and almost **82%** at 40 years. That's phenomenal longevity.

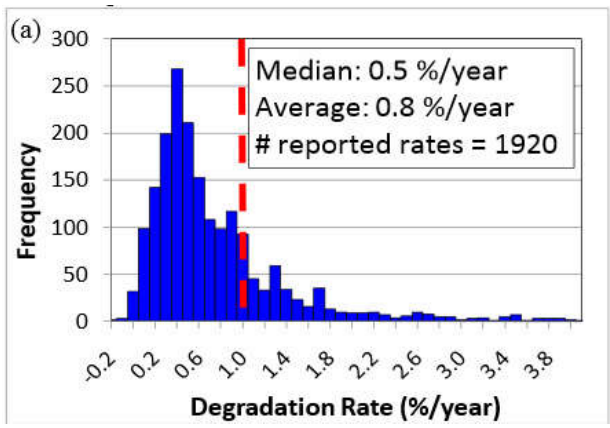

Figure 1: Degradation rates of silicon PV modules from the NREL paper *"Photovoltaic Degradation Rates - An Analytical Review"*

But that can't happen if modules aren't in position to produce maximum power over those timeframes. To reap the considerable power production rewards, modules must be mounted on durable foundations that last at *least* as long as the modules themselves.

A key part of this goal involves matching the soil type and ground conditions to the most appropriate foundation.

That means getting an accurate view of what’s under the surface at any given spot is essential. A large site may have diverse soil types which are not apparent from just one or two samples. And the consequences can be severe: unexpected soil types can create a ballooning cost disaster for the unwary project developer.

For example, one part of the selected site may have a virtually impenetrable rock formation just beneath the surface. Another part may be very sandy and loose. There are different foundation solutions for each soil type, but planning and preparation is everything.

Get The Lay of the Land With A Site Survey

The first step is carrying out a thorough **site survey exploration** from a qualified geotechnical firm. The small up-front fee should more than pay for itself when both installing the system and subsequently ensuring maintenance costs stay low for the next several decades.

A quality site survey involves digging or boring test pits at 5 to 10 locations per megawatt of installation. Each should be approximately 15 feet (4.6 m) deep.

Logging at this stage is simple: the water table level should be noted and the type of soil, rock or ledge should be recorded at one foot (0.3m) increments. Any soil condition which will prevent helical piles or driven piles from penetrating it (known as "refusal") must also be noted and at which depth.

As far as spacing is concerned, a test pit should be located at each corner of the overall array area and then evenly spaced throughout. This should ensure your site survey is statistically significant.

An entire survey job can often be completed in a single day by two workers plus a mini excavator for approximately $1,000 to $2,000.

Drill Down For The Geotechnical Details

Following the survey, a complete **geotechnical study** should be conducted by an engineering firm. This is a more sophisticated undertaking and features a smaller number of test bores which log the soil type, presence (or not) of any refusal, and water table.

The elements of a geotechnical study may include any or all of the following:

Engineer and contractor requirements	Recommendations for construction methods and slopes	Soil description (classification such as silty-sand)	Soil properties (hard, stiff, dense, loose, etc.)
Geotechnical report contents	Atterburg limits (liquid limits and plasticity index)	Compaction test (optimum moisture for compaction)	Particle distribution curves (sieve analysis)
Analysis of data given in report	Boring depth	Soil boring logs	Permeability
Soil boring equipment	Boring refusal	Direct shear tests	Soil dry density
Soil moisture content	Seismic velocity lines		

Additionally, a good geotechnical report will note corrosive factors. This ensures the optimum type of corrosion protection is selected for the foundations.

These studies, including the related reports, typically cost $5,000.

There is one limitation, however. Geotechnical reports tend to be very conservative with their embedment depth recommendations.

Hands-On Pull Testing Gives The Final Answer

This means **pull tests** are now required. A pull test uses a strain gauge to measure vertical and lateral resistance that incorporates expected wind and snow load forces at the site (these loads are normally calculated by the PV support structure engineer).

Pull tests should be conducted at varying embedment depths and at multiple locations on a site. This is especially important if different soil types have been encountered by the previous site surveys and geotechnical studies.

Also, a pull test should be conducted after selecting a foundation type to determine the minimum viable embedment depth and therefore the length and cost of screwed or driven foundations. Done correctly, this can increase profit margins without compromising site longevity.

Pull tests typically cost $6,000 to $20,000 depending on site size. They are usually organized by the PV support structure vendor.

So what kind of foundation type really *is* best for which condition?

There are primarily four to choose from.

The Key Difference Between Super- and Sub-Structure

But before we discuss optimum foundation types, it's important to make a quick distinction between the two types of infrastructure that hold a solar array in position and ready to produce power.

The **superstructure** (a.k.a. racking system) is the most visible part in publicity pictures and site visits. It fastens all the modules in precise arrays, whether in fixed positions or in daily sweeping arcs as part of single-axis, double-axis or azimuth tracking systems.

And while the superstructure is perceived as doing all the power generation support work once installed, the substructure ensures that work can *actually happen*.

And that means the **substructure**, while less visible, is no less important. The substructure provides all structural and standing support including anchors and tethers, and is of course the focus of this paper.

The 4 Main Types of Solar Ground Mount Foundation

Now let's examine the four main methods by which the superstructure and modules are supported. Each is best suited to address different installation scenarios and each has its own advantages and disadvantages.

Driven Beam Foundations: Driven beams are ideal for strong, predictable soil conditions. This includes sites with clay, gravel and dense sand where water tables are not particularly close to the surface. In general, any cohesive soil with strong pull out resistance and minimum refusal is an excellent choice for driven beams.

Picture or diagram of a driven beam goes here. Could be a diagram from a brochure or technical paper, or else an on-site photo from an installation

Driven beam installations are usually inexpensive and quick to construct as support beams are simply driven into the ground to a specified depth by pile drivers. Some pile driver machines include GPS guidance and automated installation technology which optimizes pile installation at the lowest cost possible.

But there is a key disadvantage. Driven beam foundations are impractical in adverse soil conditions. Buried boulders can cause refusals. And loose sand or gravel can also be problematic for long term beam stability.

This highlights the importance of site surveys and geotechnical studies. In fact, the preliminary findings from these research efforts can often be considered as "go or no go" studies for the feasibility of low-cost driven beams, such is their desirability for quick and cost-efficient installations.

Helical Anchor System Foundations: Helical anchor systems offer a viable solution for loose or poor soil types not well suited to driven beams, such as sand or soils with high water tables. They are widely adaptable to different soil types including areas with sporadic buried boulders.

Picture or diagram of a helical pile goes here. Could be a diagram from a brochure or technical paper, or else an on-site photo from an installation. A diagram showing the helical disc would be best, though

A helical pile is a post with a pointed tip and a large split disc near the bottom. That disc is welded onto the post at such an angle that when the post is rotated, the split disc will drill its way into the ground like a large, wide screw. It can be easily installed with auger attachments on bobcats, excavators or other equipment.

The helical disc is held in place by the mass of the column of sand above it and this creates substantial pullout resistance.

However, just as with driven beams, pull tests are necessary for helical anchors to measure the vertical and lateral forces at various embedment depths and determine the minimum depth to meet wind and snow load requirements.

Helical anchors are usually more expensive to buy and install than driven beams and hence they should not be the first choice for a solar foundation unless soil conditions dictate otherwise.

They also have one additional limitation: helical piles are unsuitable for slopes of more than 10% grade.

Earth Screw Anchor Foundations: An earth screw is a steel post with threads welded onto or machined into it to create a large screw. These foundations are usually installed into predrilled holes in underlying boulders, bedrock or rock ledges. They are screwing into place with bobcats, excavators or other equipment using auger attachments.

Picture or diagram of an earth screw goes here. Could be a diagram from a brochure or technical paper, or else an on-site photo from an installation. A diagram showing the helical disc would be best, though

Earth screws can also be installed *without* predrilled holes if there are no refusal issues. However, the normal cost of earth screw installation is high due to the need for separate equipment and the associated time and labor to predrill each hole.

However, in the case of very rocky soil, earth screws may be the best solution.

That is because the only other choice in such conditions is a driven beam foundation which will experience high levels of refusal and which subsequently requires *much larger* pre-drilled holes than earth screws to reach a suitable depth. There is also a substantial time and cost consideration for the concrete which must be poured around each driven beam to stabilize it in a predrilled hole.

In comparison, earth screw threads are much more sticky, do not require poured concrete, and create substantial pullout resistance once a suitable predrilled hole is prepared.

Ballasted Foundation: This is the most expensive of the four solar foundation solutions and is comprised of concrete footings. These weigh down the substructure much like a series of large paperweights.

Picture or diagram of a ballasted foundation goes here. Could be a diagram from a brochure or technical paper, or else an on-site photo from an installation. A diagram showing the helical disc would be best, though

Ballast should only used in projects where it is impossible or impractical to penetrate the ground. Such sites include sealed landfills for which the protective barriers must not be breached to avoid environmentally hazardous site contamination.

However, any site that combines high refusal rates with low soil cohesiveness and a high water table is a good candidate for a ballasted foundation since earth screws are not effective in sand and helical piles will not install if refusal is present.

Ballast is very flexible and controllable as it can be created from concrete poured on-site or from precast concrete pavers placed in appropriate positions.

However, a significant part of the high cost is the components associated with concrete and concrete forms. This means ballast is normally not practical for small installations unless a low price for the concrete can be obtained.

Hybrid Foundation: On sites with multiple soil types and gradients, a mix of appropriate support methods might be required to address each one. This must be decided by the project developer on a case-by-case basis.

Addressing Wet or Corrosive Soil Conditions With Appropriate Countermeasures

There's one last step to ensuring that your solar array foundation will last as long as intended.

The moisture content, conductivity of soil media, pH and the oxygen concentration can all have adverse effects on the long term viability of a solar project.

Undrained water can make clay, sand, and silty soils softer. Excessive drainage can wash away or erode gravelly or rocky soils. And if your site is exposed to freezing temperatures, expanding ice can wreak havoc on the soil condition and cohesiveness, including the bedrock beneath it.

Chemistry can have an important effect too. Extremely acidic or alkaline soils can eat away buried organic matter to leave vacant spaces prone to collapse or shifting. Soils with extreme pH levels can also chemically attack the foundation itself and weaken its structural integrity.

A proper geotechnical survey will spot these issues before construction and recommend appropriate actions. This is particularly important when foundation pilings will intersect different soil boundaries or layers in the same area.

Appropriate mitigation efforts include:

a) Prepping the site for drainage by grading or compacting the ground, or else by creating drainage channels or ditches as needed. Each measure will be highly site specific but the desired result is to minimize soil moisture and ensure an appropriate level of drainage during all seasons and weather conditions.

b) Using foundations with protective coatings suitable for the soil chemistry at hand.

Most foundation substructures today are cost effectively galvanized (coated in self-sacrificing zinc) in a highly controlled steel mill certified process called pre-galvanization.

A thick pre-galvanized coating such as G235 has seen widespread adoption due to a 40+ year lifespan in normal soil conditions. G235 is most suitable for solutions such as driven beams, helical anchors and earth screws that penetrate the ground.

Meanwhile, thinner and less costly G90 and G140 zinc coatings are acceptable for ballasted ground foundations since they remain above the soil surface.

However, pre-galvanized zinc alone is sometimes not enough to protect against electrochemical reactions in highly acidic or alkaline soil. The alternatives include custom retardant epoxy coatings, coal tar paint (especially in acidic soil) and concrete embedments to encase underground metal entirely within concrete. Each of these add to costs, but may be vital to ensuring the longevity of the project in adverse soil conditions.

Summary

It is very possible to create long-lasting foundations which hold solar arrays firmly in place for the life of the modules.

- Proper site surveys and geotechnical studies must be completed and analyzed
- Pull tests must be carried out after determining the wind and snow loads for the site
- The correct choice of foundation (driven beam, helical pile, earth screw, ballast, or a combination thereof) must be selected for the site soil conditions
- Foundations must be protected from excessive moisture and water levels as well as extreme soil chemistry in certain cases

Interested in learning more so your next project will go smoothly, predictably and profitably?

At XYZ Racking, our engineers are experts on diagnosing soil types, moisture, and corrosive factors. They have XX years of experience in selecting the most appropriate foundation system and mitigation measures needed to ensure a long and healthy life for your ground mount solar system.

With Professional Geologists and Engineers on staff, we can work directly with local technical teams to ensure cost-effective and optimized designs that work hand in hand with your project budget and ambitions.

For case studies, product brochures, additional white papers, video tutorials and expert consultations on how the XYZ Racking can make your next solar project easier, quicker and with a longer lifespan than ever, reach out to an XYZ representative today by clicking HERE.

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Today's solar modules are producing more power for longer than ever before.

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Check out our latest white paper "How To Choose A Ground-Mount Solar Foundation That Lasts 40 Years Or More". It covers everything you need to know to ensure you'll avoid wasted time and money on your next ground-mount solar PV project.

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