Using Composite Mounting Pads to Rapidly and Reliably Deploy EV Charging Infrastructure

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1. Introduction

Sales of electric vehicles (EV) are expected to expand rapidly in the US in the coming years. Economics aside, there are growing social and political initiatives toward "clean" energy that will push this to become reality. A number of market forecasts indicate electric vehicles will account for nearly 1 in 5 of all vehicles sold within the next 10 years. It is estimated approximately 3 million EVs will be sold in the US in 2028. A recent forecast (pre-Covid) is shown below in figure 1. Increasing electric vehicle sales in turn drives the need for widely available public electric vehicle charging stations (EVC).

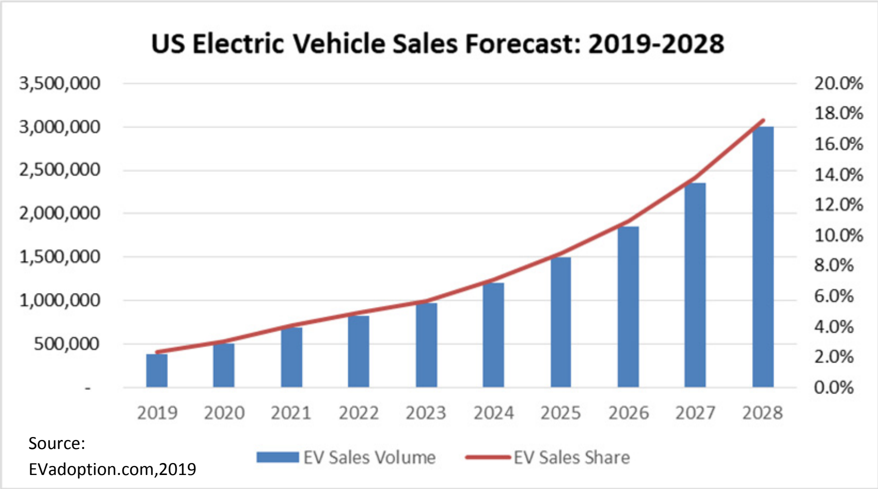


Fig 1: US EV forecast through 2028

A rule of thumb by industry analysts is there need be on the order of 20 public EVC stations per EV on the road to support the ecosystem. There were just over 60,000 charging stations in the US at the end of 2019. Thus tens of thousands will need to be deployed every year for some time as the market grows. To help facilitate this growth, there is a novel type of installation practice using new composite buried mounting pads (CPAD) to enable rapid deployment of EV charging stations. CPADs provide same day installation of public electric vehicle charging stations which is not possible with traditional concrete pad mounting.

The Charles CPAD is a buried mounting platform that is used to quickly and easily install different types of outdoor equipment. It has been commonly used for generators, Telecommunications cabinets, and more recently, electric vehicle charging equipment.

Buried composite mounting pads are lightweight, yet extremely strong and durable. In fact they provide in most cases increased mounting stability compared with comparable sized concrete pads. CPADs provide the lowest cost of total installation for contractors, property owners, and network providers alike. While the industry is familiar with concrete, CPADs are a relatively new mounting technology. A common question or concern is how well do CPADs hold up in stress conditions such as heavy wind as might be experienced in some parts of the country. The paper will address these questions and explain the remarkable mounting stability that is provided with CPADs

2. CPAD Advantages

> ***"CPAD deployment provides same day installation of public electric vehicle charging stations which is not possible with traditional concrete pad mounting"***

Composite pads are often used instead of poured-in-place concrete or pre-cast concrete pads. The CPAD has several advantages over poured-in-place concrete. Poured concrete requires a construction permit along with an inspection which adds logistics, cost, and time to a project. In addition there are coordination logistics for an electrical contractor with a cement or equipment rental company. And poured concrete needs to cure. All of this adds several days to the project time and is not needed with CPAD deployments. Using CPADs for deployment provides same day installation of public electric vehicle charging stations which is not possible with traditional concrete pad mounting

To reduce time and complexity, some installers have started to use pre-cast concrete pads for EVC deployments. While this eliminates some of the drawbacks of poured-in-place concrete such as permitting and curing, pre-cast pads are extremely heavy. Pre-cast pads need to be several times the weight of the equipment being mounted. These pads can weigh well over a thousand pounds when mounting DC fast chargers. Pre-cast pads become very difficult to maneuver on site and require special equipment to do so. EVC CPADs typically weigh between 40 to 75 pounds and are easily and safely maneuvered on site. CPADs can easily be brought to harder-to-reach sites. CPAD installation can be conducted by one or two person crews depending on the size of the charger, another important consideration in today's COVID pandemic environment. The use of CPADs aids in social distancing for electrical vehicle charging equipment installers, which is an important consideration of late. Easy to store, easy to transport, easy to put in place, CPADs facilitate quick and simple roll outs of EV charging equipment any time any place.

> ***"The use of CPADs can also aide in social distancing for electrical vehicle charging equipment installers, which is an important consideration of late"***

3. What is a CPAD?

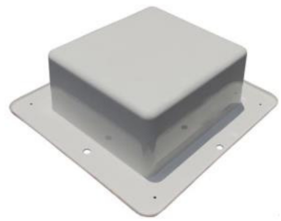


Fig 2 Typical CPAD

Charles Industries composite mounting pads (CPAD) are made of a composite fiberglass and polyester resin mixture. CPADs provide a strong, durable, and lightweight ground mounting platform. Charles composite material is laminated and infused in a closed mold under vacuum pressure which creates a solid water impervious structure. The material is gel-coated to provide a UV-resistant surface. CPADs are available in a variety of sizes to meet various equipment and site needs. The material meets all of the environmental and reliability properties defined in SCTE/ANSI-77 which includes: impact resistance, flammability, sunlight exposure, chemical resistance, fire, and water absorption. As a testament to CPAD durability and reliability, it is made from similar material that is used to produce wind turbines, ships, and aircraft. A CPAD is shown to the right in figure 2. Although the top surface of the CPAD is a very strong and durable, it can easily be drilled or cut through for mounting bolts and pathways.

4. CPAD Mounting Stability

The CPAD attains its mounting stability through soil backfill. See the depiction below.

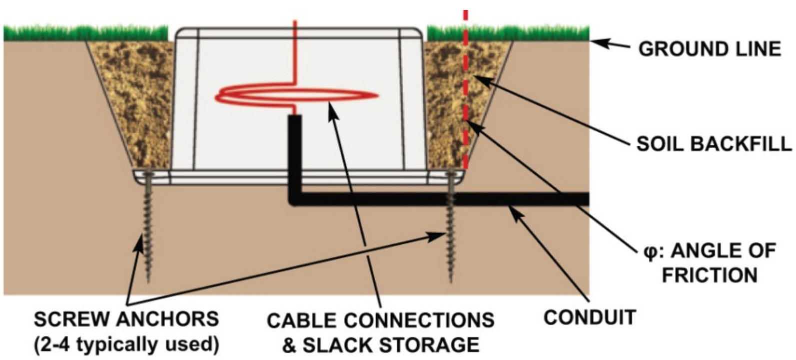


Fig 3 Cutaway view of mounted CPAD

Mounting stability is provided from the weight of the soil backfill. There can be a range of mounting strength depending on the compactness of the soil. Soil conditions vary greatly by location and it is not practical to do a soil analysis at each installation location. Soil types have been categorized by a couple of industry organizations, notably International Building Code (IBC) and ASTM. Charles Industries has conducted analysis to provide a minimum stability rating based on worst case soil conditions of loose, sandy soil as defined as IBC class 5 and ASTM class 4B. Additional mounting strength, if desired, can be achieved through the use of aluminum screw anchors. An 18 inch screw anchor provides at least an additional 200 pound pullout force under worst case loose sandy soil. A 26 inch anchor provides 360 pound pullout force in similar conditions.

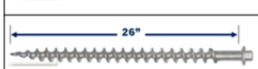
Anchor	Pull out per anchor
	200 lb. min Worst case loose sandy soil
	360 lb. min Worst case loose sandy soil

Fig 4 Available screw anchors

4.a. How much stability is required?

Let’s consider what can happen to equipment mounted to a pad on the ground. The equipment can come off of the pad or the pad can come out of the ground. First let’s consider the equipment mounted to the pad.

The standard mounting hardware consists of what are called toggle bolts. These bolts are very easy to use as they can be inserted through a hole in the platform so they can be installed after the CPAD has been put in the ground. These toggle bolts have been validated to require over 3200 pounds of force to pull through the pad. This is more than adequate for most requirements. Installing in an area of seismic concern, optional “weldnut” bolts are available which provide more than 6,000 pounds of pull through.

Toggle Bolt
> 3200 lb.
Pull-through
force

Weldnut
> 6000 lb.
Pull-through
force

Fig 5 Equipment mounting hardware

The toggle bolt has the equivalent strength to using a 3/8 inch by 3 inch concrete wedge anchor and the weldnut is equivalent to using a 1 inch by 4 inch concrete wedge anchor.

This establishes the equipment will stay mounted to the CPAD. The main consideration is now whether the pad will stay in the ground. It is of interest to determine what force could cause the unit to come out of the ground. The mostly likely force for outside mounted structures will the force caused by heavy wind.

4. b. Wind Resistance Design Guidelines

There are IBC wind design guidelines that have been updated in ASCE 7-16. EVC equipment is considered to be in risk category 2 as an unoccupied structure. Reviewing wind guidelines in the chart below, one can see that a design guideline of 150 mph will cover nearly all the country. 150 mph is also used by Telcordia as a design guideline for outdoor equipment, although there are some locations such as South Florida that may require up to 180 mph wind resistance. To help engineers and installers determine the best CPAD to mount their equipment, Charles Industries has developed a wind stability model which incorporates the size of the mounted equipment, the CPAD, and wind conditions. Larger or deeper CPADs may be warranted if installing in higher wind risk areas such as South Florida. An overview of the model follows.

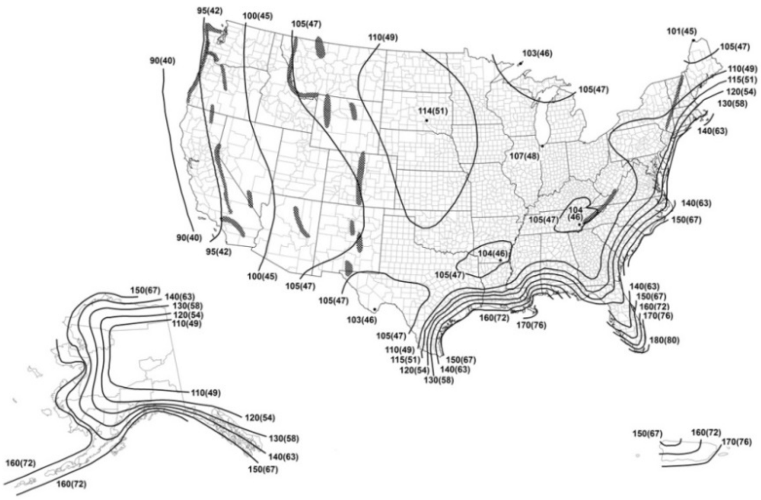


Fig 6 ASCE 7-16 Risk Category 2 Wind Design Guidelines

4. c. Wind Stability Modeling

Wind stability of equipment mounted on a CPAD will depend on the wind force on the equipment, the weight of the equipment, and the stability or pull out force of the CPAD in the ground. The wind force on the equipment depends on the dimensions and shape of the equipment.

The stability of the CPAD in the ground which, defined as pull out force, is based on the weight of the soil backfill. This depends on the size and depth of the pad along with compactness of the soil. Charles' analysis uses worst case soil conditions of loose sandy soil. Based on the size and depth of the pad, the weight of the soil can be calculated geometrically. Loose sandy soil with zero soil friction is assumed as the worst case and the weight of the soil equals the pull-out force.

4. d. Calculating CPAD Pull-out Force from the Ground

The volume of soil displacement is calculated geometrically for all of the 4 sides and 4 corners of the CPAD. Note that the CPAD platform should be installed 2 inches above ground so the area below ground is the depth minus 2 inches. The weight of the soil is the volume of displacement times the density of the soil. The soil density for loose sandy soil is 104.88 lb./ft^3.

Estimated worst case pullout resistance for a couple standard size CPADs has been calculated and is shown below. Concrete pads of similar size will need to be well over 2 feet thick to provide the same level of mounting stability.

Example Pad Size	CPAD* Pull out force	6 inch Concrete	12 inch Concrete	Concrete thickness to equal CPAD
29" x 26"	**1905 lb. min.**	391 lb.	782 lb.	2.4 feet
40" x 36"	**3505 lb. min.**	750 lb.	1500 lb.	2.3 feet

Fig 7 CPAD Mounting Stability compared with concrete pads

4. e. Wind Load Modeling

Determining the wind load on a charger mounted to a CPAD will be composed of two components. One is the wind velocity pressure and the other is the wind load on an open structure. Charles has modeled EVCs mounted on CPADs resistance to wind using formulas from the building industry and summarized on the following page.

Referencing ASCE 7-16, velocity pressure, qz, evaluated at height z shall be calculated by the following equation: $qz = 0.00256\ KzKztKdV^2I$ (lb/ft^2)

Kz is the velocity pressure exposure coefficient (determined to be 0.85)
Kzt is the topographic factor (determined to be 1)
Kd is the wind directionality factor (no combined wind loading and determined to be 1
V is the wind velocity (mph)
I is importance factor (determined to be 1 as risk category 2)
V is the wind velocity (mph)

The wind force on the EV charger is as below considering the worst case of wind blowing directly on the broadside of the charger. The wind load force will be determined by:

Fwind = qzGCfAf (lb)

qz is velocity pressure at the center of the area
G is gust factor (assumed 0.85 for rigid structure)
Cf is the net force coefficient (determined as 1.2)
Af is the area normal to the wind

We are ultimately looking to determine the force required to lift the CPAD and EVC out of the ground. This can be thought of the force exerted on the base of the CPAD or on a screw anchor which has been driven into the ground through the base of the CPAD. We will assume for this exercise 2 anchors have been implanted on each long side. If there is negative force on the anchor, the anchor is compressed and the mounted unit stays in the ground without need of the anchor. This is a very stable condition with the anchor only providing stability margin. If the result of the analysis shows there is a pulling force of less than 200 lb. with an 18 inch anchor, the unit stays in the ground. If the pulling force is greater than 200 lb. the unit has the possibility of pulling out of the ground. Either more anchors can be used or 26” anchors which provide 360 lb. pull-out resistance each can be used. Alternatively a larger sized CPAD can be used. Some example of analysis on commonly used EVC with a standard CPAD are shown in following section of 4.f.

4. f. CPAD Wind Stability Calculation

The force on each anchor (assuming 2 anchors on a side is calculated as:

$$Fanchor = \frac{1}{N}\left[fwind\left(\frac{H}{2d} + \frac{h}{d}\right) - \frac{Wsoil + Wcharger}{2}\right]$$

Fanchor is pulling force on each anchor
Fwind is the wind force on the center of the charger
H is the height of the charger
h is the depth of the CPAD
d is the distance between the anchors on the side
N is the number of anchors on one side

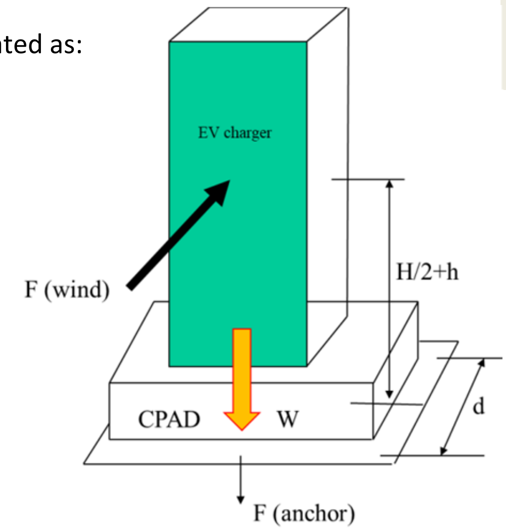


Fig 8 EVC on CPAD model

In the table below Charles has calculated the pull out force exerted on anchor for a few commonly used EV chargers mounted in a standard available CPAD stressed under a 150 mph wind condition. Two are for large 50 KW DC fast chargers and one of the larger versions of a commercial level 2 charger. These are using worst case assumptions of loose sandy soil and wind directly on the center of the long side of the charger. Under these worst case assumptions the mounted unit shows excellent stability and will not come out of the ground with 150 mph winds.

EVC Maker	Model	EVC Dimensions (W x H x D inches)	Weight (lbs)	CPAD used	CPAD Dimensions	CPAD Platform	Soil weight (lb)	150 mph		
								Wind load (lbs)	Anchors per side	Pulling force on each anchor (lbs)
ABB	54	30.7 x 74.8 x 22	775	CPAD-M1BUNI4036	60” x 52” x 18”	40” x 36”	3504	693	2	-568
BTC Power	Slim line	34 x 86 x 22	850	CPAD-M1BUNI4036	60” x 52” x 18”	40” x 36”	3504	882	2	-385
Chargepoint	CT4021	24" x 72" x 12"	115	CPAD-S1BUNI2629	45" x 42" x 15"	29" x 26"	1905	521	2	-56

Fig 9 wind stability results with example
EVC on a standard CPAD

Charles has empirically validated this analysis through some real work pull testing. Equipment that was mounted to a CPAD without anchors was pulled on by a winch. The model predicted that the CPAD would exceed 160 mph. In fact a force equivalent to 166 mph was required by observing any movement of the ground around the buried CPAD.

The actual wind force stability will depend on the size, shape, and weight of the equipment and the size of the CPAD being used. Charles can provide guidance to customers for help in selecting the best CPAD for a particular project or program.

5. Installation Process

Installing a CPAD is straightforward process and is accomplished with minimal manpower. Typically the installation can be completed in the same day.

Step 1: Dig a hole and level with gravel

Step 2: Place CPAD in the opening & Cut opening for mounting and cables (this can be done in advance)

Step 3 Backfill with soil

Step 4: Place and secure equipment on CPAD

FINISHED!

6. Cost implications

Naturally project costs can vary widely depending on a number of factors. Generally speaking an installation project using CPADs may have a slightly higher material cost, with much lower labor costs providing an overall lower cost of installation. Most significantly there is a tremendous time savings.

As an example we can look at a small project of installing three commercial level 2 chargers. Let's just consider the physical installation and not the cost of the charger or electrical which is similar regardless of installation method.

To install three level 2 chargers, it took two men 4 hours at $75/hour. The total allocated labor cost to this portion of the job is $600. The cost of material was approximately $1200. So the total cost for just the physical installation was $1800. The installation was completed in less than one day.

The alternative approach using traditional poured concrete was estimated to be $400 for material and $1800 for labor. There would be a 1-2 day wait time for building inspection and 3 days waiting for the concrete to cure. The labor would need to come to the site three times. It was estimated that the total installation time would be 6 to 7 days.

Overall the CPAD method proved a 20% cost savings and 80% time savings. While this can vary depending on size of the job, accessibility to the site, and local jurisdiction requirements; in nearly every case there will be a saving of both time and money using CPAD mounting technology.

7. Summary comparison

A comparison of using concrete and CPADs for mounting EVC is shown in the below table. Although concrete has traditionally been used to mount EV chargers, CPAD has many advantages including an overall lower cost of installation.

Parameter	Poured Concrete	CPAD	Notes
Cycle time	5-7 days	1 day	CPAD no permitting Cement long cure time
Convenience	Lower	Higher	CPAD lightweight & easy to reach remote site CPAD relocatable
Safety	Lower	Higher	CPAD non-conductive CPAD no heavy equipment
Durability	Lower	Higher	Cement can crack
Material cost	Lower	Higher	CPAD slight higher material
Labor cost	Higher	Lower	Cement higher labor hours & larger crew
Total installed cost	Higher	Lower	CPAD lowest installed cost

Fig 10 Comparing CPAD to Concrete Mounting

8. Conclusion

In order to meet local and regional political initiatives to move toward "clean" electric vehicles in the coming years, an expansive build-out of publically available level 2 and DC fast electric vehicle charging stations will be needed. Using a new novel approach for physical installation using composite mounting pads has many advantages over traditional use of concrete pads. CPADs provide a quicker, simpler, safer, and more cost effective method of rapidly rolling out these stations. Charles has modeled different scenarios for deploying various sizes of commercial EV charging equipment including Level 2 pedestals and DC Fast chargers. It can be concluded that Charles Industries' CPADs provide more than adequate ability to withstand high wind conditions throughout North America. Common EVCs mounted on standard CPADs are rated to withstand more than 150 mph wind conditions. Further, depending on the equipment and CPAD size, greater than 180 mph winds can be withstood.

Charles Industries' CPADs are manufactured in the US and come in several sizes to best accommodate the equipment being deployed. More information can be found at http://www.charlesindustries.com/main/te_CPAD.htm or by contacting Charles Industries at 1-847-806-6300.