Concrete-Encased Electrodes Required

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Part III of Article 250 provides the important concept of a grounding electrode system, where all grounding electrodes are required to be bonded together and function as a system as indicated in Section 250.50. Rather than reliance on a single grounding electrode to perform its function over the life of the electrical installation, the NEC requires the formation of a system of electrodes "that are present at each building or structure served." There is no doubt that building a system of electrodes adds a level of reliability and helps ensure system performance over a long period of time, usually the duration of the life of a building or structure. It is important to understand that this requirement applies generally to all buildings or structures and is not limited in application to just commercial or industrial installations. Residential construction is included in these requirements.

Several questions have been raised about recent revisions to NEC 250.50, which provides the minimum requirements for establishing a grounding electrode system. Let's take a closer look at what changed in the Code and what these changes mean to the electrical industry as a whole, beginning with a review of the purpose of and requirements contained in 250.50. This rule clearly calls for all grounding electrodes present at each building or structure served to be used to form a grounding electrode system. If there are multiple grounding electrodes of any of the types listed in 250.52(A)(1) through (A)(6), they all are required to be used to form the grounding electrode system (see table 1).

250.52(A)(1)	Metal Underground Water Pipe
250.52(A)(2)	Metal Frame of the Building or Structure
250.52(A)(3)	Concrete-Encased Electrode
250.52(A)(4)	Ground Ring
250.52(A)(5)	Rod and Pipe Electrodes
250.52(A)(6)	Plate Electrodes

Table 1. These grounding electrodes are required to be used where present. If any of these electrodes are inherent to the building or structure, they shall be used in the grounding electrode system.

Note that there are no options here or choices of any combinations or quantities of grounding electrodes that can be used to establish this required system. The Code says all of them shall be used. As with many other aspects of building construction, this may involve some planning and coordination. The primary purpose of this rule is to require all grounding electrodes to function as a system. This is the grounding foundation of the electrical power system for the building or structure. The goal is to establish the most effective connection to the earth. Grounding electrode effectiveness is dependent on it.

Let's compare Section 250.50 of NEC-2002 with how it was revised for NEC-2005.

NEC-2002
250.50 Grounding Electrode System.

If available on the premises at each building or structure served, each item in 250.52(A)(1) through (A)(6) shall be bonded together to form the grounding electrode system. Where none of these electrodes are available, one or more of the electrodes specified in 250.52(A)(4) through (A)(7) shall be installed and used [emphasis added].

NEC-2005
250.50 Grounding Electrode System.

250.52(A)(4)	Ground Ring
250.52(A)(5)	Rod and Pipe Electrodes
250.52(A)(6)	Plate Electrodes
250.52(A)(7)	Other Local Metal Underground Systems or Structures

Table 2. Any one or more of the grounding electrodes in this table are required to be installed and used where any of the electrodes identified in 250.52(A)(1) through (A)(6) are not there to use.

All grounding electrodes as described in 250.52(A)(1) through (A)(6) that are present at each building or structure served shall be bonded together to form the grounding electrode system. Where none of these grounding electrodes exist, one or more of the grounding electrodes specified in 250.52(A)(4) through (A)(7) shall be installed and used [emphasis added; see table 2]

The More Things Change the More Things Stay the Same

The language in Section 250.50 in NEC-2002 and in previous editions resulted in varying interpretations and inconsistencies in how the requirement was being applied to installations in the field. This is one of the principle reasons that necessitated the revision. The other primary reason is to ensure that the benefits of all grounding electrodes present are utilized. There really is no difference in what has always been required by the Code. For some, this may have been an eye opener or even a major change. This is probably owing to the vague language used in this section previously. The revised wording clarifies that when it comes to establishing a grounding electrode system, there are few options. If grounding electrodes are inherent to the construction of a building or structure, they are required to be used for the grounding electrode system—all of them.

Grounding Electrodes to be Used Where Present

Previous editions of the Code used the words “”if available”" in this section which was the primary reason for the wide range of applications of this rule. The NEC Manual of Style indicates that the Code shall not contain requirements that are vague or unenforceable, and the word “available” is one such word listed in the Style Manual that should be avoided for that reason. Many in the industry feel that there has been a significant change in requirements of this section when in reality the requirement has not been changed, just clarified. The challenge is for those jurisdictions or other entities that have the responsibility for interpreting the rules and applying them in the field to installations and systems. This rule has been clarified to be more in step with what was always the initial objective. The words “if available” were removed and the section was revised to provide needed clarification and guidance as to which grounding electrodes are required to be used to form the system. The Code says “all,” which should remove any doubt as to what is required.

Where the words “”if available”" were used in previous editions of the Code in this section, they were to mean where there is an electrode that meets the criteria of any of the grounding electrodes specified in Section 250.52(A) (1) through (6), then it should be used in the grounding electrode system. Let’s face it, “if available” was not the best language to use in a mandatory requirement of the Code.

Existing Buildings or Structures

It is also recognized that buildings or structures will exist in which electrical power systems will be used and installed. For those situations this section of the Code has been revised to include an exception that relaxes the requirements for using the concrete-encased grounding electrode. The technical committee was very specific to clearly indicate in the exception that concrete-encased electrodes of pre-existing buildings or structures are not required to be part of the grounding electrode system where using them would involve disturbing existing concrete. Otherwise the Code requires them to be used in the grounding electrode system, which could include planning and coordination to make this happen, just as planning and coordination is required for many other aspects of the building construction. For many jurisdictions this is not an issue because it has become the common practice in new construction. For many contractors as well as jurisdictions this will involve a different approach or an adjustment, but should result in improved effectiveness of an essential safety component of the electrical system, the grounding electrode system.

Let’s look at an example to help put things in perspective. A similar installation that should be inspected is the equipotential bonding grid connections to the rebar system for a swimming pool installation. The installation and inspection are critical, and generally coordination is established to accomplish both. This inspection is generally required prior to the pool concrete being installed. Jurisdictions typically coordinate this inspection to verify the required bonding connections to the rebar are installed. There is no option for this requirement and no words such as “”if available”" are used in these rules associated with these equipotential bonding grid requirements. It is not optional and is required for safety. It’s important. In comparison, at some point in time during construction of the building or structure the reinforcing steel in concrete footings is accessible (not available) for making this installation, connection and inspection. The Code is silent on the coordination of the work and always has been. That is the responsibility of the contractors. Many inspection jurisdictions have had success with cross-training inspectors who already verify reinforcing rods in building footings for compliance with the structural code to also verify the concrete-encased grounding electrode conductor connection is also installed. This is just one of several ways to handle this from the inspection standpoint. There are many other ways to handle this, but generally it just involves a small effort in planning to yield the best result for safety.

Electrode Effectiveness

Photo 1. Vapor barriers create isolation between the concrete and the earth. These are not suitable for use as concrete-encased grounding electrodes. (Photo courtesy of Robert Jones, IEC)

Concrete-encased grounding electrodes normally have low resistance in the connection to the earth and are proven reliable as either the sole electrode or as part of a grounding electrode system. The findings of Herbert G. Ufer* that concrete-encased metal objects were effective in providing improved grounding under adverse soil conditions suggests that the reinforced framework of footings and structural members buildings would provide an effective grounding means and function. Ensuing tests of these electrodes in high, medium, and low resistivity soils indicate that the grounding capability of such reinforced footings (per unit) is equivalent to that of other conventional grounding electrodes and superior to them under high soil resistivity conditions. In addition, where a much larger number of concrete footings and structural column footings are used, they provide more effective grounding under all soil conditions than previous grounding systems.

Photo 2. Close up. Vapor barriers create isolation between the concrete and the earth. These are not suitable for use as concrete-encased electrodes.

For more detailed information on studies relating to concrete-encased electrodes see 1970 IEEE Vol. IGA-6, No. 4 July/August by Eugene J. Fagan and Ralph E. Lee and the “Investigation of footing-type grounding electrodes for electrical installations” by *Herbert G. Ufer (IEEE Trans. Power Apparatus and Systems, Vol. 83 p. 1042-1048 October 1964).

Let’s address a couple of other common questions since we’re into this topic fairly deep now anyway. Where a footing is separated from the earth by a plastic or other insulating (vapor) barrier, the concrete-encased electrode is not present (see photos 1 and 2). The Code defines grounding electrode as “a device that establishes an electrical connection to the earth.” The other challenge that will be encountered in the field is the expanded use of encapsulated or coated reinforcing bars in footings. Obviously, footings utilizing coated rebar would not be suitable for use as concrete-encased grounding electrodes.

A Closer Look

The National Association of Home Builders has recently submitted seven excellent questions related to the requirements for concrete-encased grounding electrodes. Let's take a closer look at these questions and address each one specifically.

1. Are more than a total of 20 feet of reinforcing steel located in a footing required for compliance with Sections 250.50 and 250.52? The 20 feet can include pieces of rebar that are tied together in the usual manner. In other words, if more than 20 feet of reinforcing steel is located in the footing does all of the steel need to be bonded together to form the electrode, or will a minimum of 20 feet of the steel be the maximum length required? This is important to understand as having footings at different levels (step footings) may occur. This also may include concrete pads for the support for interior columns, or many concrete piers to support the entire structure. If all of the steel needs to be bonded together this would require a bonding conductor to jump from one footing to the other and possibly the pads, or to each separate pier.

Answer: The Code establishes the minimum requisite, which means one is required to do at least that much. The answer is yes; a single section of rebar in a length of 6.0 m (20 ft) satisfies the requirements of Section 250.52(A)(3). The minimum length of 6.0 m (20 ft) can be accomplished by multiple reinforcing bars being bonded together using the usual steel tie wire as indicated in the last sentence of this section. To answer the second part of this question, if there are multiple concrete-encased electrodes in the same overall concrete footing that are not tied together by the usual tie wire, then by the current minimum requirements in the Code, they should be used and bonded together. This situation can be compared to conditions where multiple water pipe grounding electrodes are in the same structure. They all are required to be used in the grounding electrode system, without exception.

2. If steel reinforcement is not normally contained in the footing design, can the installation of only 20 feet of ½ inch rebar in the footing serve as the primary grounding electrode?

Answer: Yes. A length of reinforcing bar not less than 6.0 m (20 ft) meeting the criteria in Section 250.52(A)(3) can be installed within and near the bottom of a concrete footing that has little or no reinforcing rods and would meet the Code criteria for concrete-encased grounding electrode. However, the NEC does not require a length of reinforcing bar to be installed in a concrete footing where it is not required by any structural code.

3. If reinforcing steel and a metal water pipe are used as the grounding electrode(s) for the system, is a supplemental ground rod required, even if the 25 ohms or less resistance cannot be achieved?

Answer: No. A grounding electrode system does not have to meet the "25 ohms or less" resistance requirements contained in Section 250.56. A single electrode of the rod, pipe, or plate type is required to meet the "25 ohms or less" requirement in 250.56. The concrete-encased grounding electrode can supplement the water pipe electrode as required by Section 250.53(D)(2). This section indicates that the water pipe electrode must be supplemented by any of the types specified in 250.52(A)(2) through (A)(7). The concrete-encased electrode is included. A rod, pipe, or plate grounding electrode would not be required in this particular case.

4. If no footing is used in the construction of the building, will the typical current method of using the metal water piping and/or ground rods meet the provisions for the grounding electrode system?

Answer: Yes. The requirements of 250.50 hold consistent in this application. If there were no concrete-encased electrode to use, it would not have to be installed and used. Section 250.50 requires grounding electrodes that are there for use, to be used. If no electrodes exist, then one or more of the grounding electrodes in Section 250.52(A)(4) through (A)(7) must be installed and used.

5. Where there may be a total of 20 feet of rebar in a footing but it consists of a few small pieces separated by many feet, would these small, remotely placed pieces be required to be bonded together to serve as an electrode?

Answer: No. The last sentence of the rule in 250.52(A)(3) is permissive text according to the NEC Style Manual. The smaller sections of reinforcing bars could be bonded together using the usual steel tie wire to form a 6.0 m (20 ft) length and then used, but it would not be a requirement. This section also offers the alternative of creating a concrete-encased grounding electrode by installing a 6.0 m (20 ft) length of copper wire sized not less than 4 AWG copper, but this is also not a requirement, just another option. Where the reinforcing bars are inherent to the construction and meet the criteria provided in Section 250.52(A)(3), then they become required electrodes to be used in the system.

6. Are new footings containing steel reinforcement for an addition to an existing building exempt from these provisions?

Answer: Possibly. I always try to stick to more direct answers, but when the answer will be primarily dependant on the judgment of the AHJ, it is the best approach. There is no "yes" or "no" answer for this question. The answer is going to be based on how each local jurisdiction handles existing installations or alterations to existing buildings or structures through their own specific administrative provisions or local code rules.

7. If a new addition is constructed as noted above and the existing electric service is upgraded, would the reinforcing steel now need to be used as an electrode, even if the panel is located remote from the new addition?

Answer: Based on the information provided in this question, the answer would be yes, the concrete-encased electrode installed in the new footings would be required to be used as part of the grounding electrode system for the new service being installed. This situation will be handled individually by each local jurisdiction enforcing the code in that particular area. Each existing installation is going to have to be handled case by case. There are going to be situations where it would be practical to accomplish using a concrete-encased grounding electrode in a remodel or retrofit that includes installing new or additional building footings. There will be other instances where it will be less practical, if it is possible at all. Judgment by the AHJ in those situations is going to have to be applied.

Making the Best Decision

There were many different discussions and interpretations of the words “if available” as previously used in this section. Some contended that if a building is constructed, then at some point during the construction, the concrete-encased electrode is required to be installed and made part of the grounding electrode system. This is one reason many jurisdictions adopt local amendments to the NEC to require concrete-encased electrodes to be installed. This eliminated any doubt as to whether or not it was required. Many jurisdictions feel that it should not be viewed as a coordination problem between subcontractors on the jobsite. In contrast, there are those who feel that if the concrete footings or foundation is already in place prior to the electrical contractor’s presence on the construction site, access to the rebar system for establishing a concrete-encased electrode is not practical, and therefore is unavailable. Is this the best approach? There are varying opinions when addressing this question—each opinion is directly proportional to the knowledge of the fundamental purposes of grounding an individual has. The grounding electrode system is an important, vital part of the electrical distribution safety system and decisions relative to the grounding electrode system and what grounding electrodes are used as part of this system should be carefully considered. The revision to Section 250.50 should add considerable consistency to a requirement that appears to have had a wide variety of inconsistent application. This is a good thing for the industry, not to mention the benefit to the electrode system in the way of electrode effectiveness and lower resistances in the connection to ground.

Summary

Section 250.50 has only been revised to clarify what was previously required. Remember the goal when establishing a grounding electrode or grounding electrode system for a building or structure should be to strive for the best possible connection to the earth. Concrete-encased electrodes have a proven record of providing this. The grounding electrode is an essential component of the electrical safety system, just as a footing is an essential component of the building’s structural integrity. Buildings or structures require a solid foundation on which they should be built just as the grounding electrode system serves as the foundation for the electrical power service or system. Many jurisdictions are not having an issue with this revision and understand it. Hopefully this article has brought a more thorough perspective of the revision. The revision to the NEC was not intended to be a significant change in requirements, just to clarify what was already required. It is apparent the inconsistencies in installations and inspections were created by the use of the words “if available.” A look back at previous editions of the NEC reveals that the words “if available” have been used in the grounding electrode rules back as far as the late 1920s and early 1930s. The answers to these questions have been addressed based on the minimum requirements of the NEC. As always, you should check with the local authority having jurisdiction for any local requirements that may amend or modify the minimum NEC requirements.