6.4 Mechanical, Electrical, and Plumbing Components

6.4.7 Electrical and Communications Equipment

6.4.7.3 Transformers

Transformers may be dry-type or liquid filled; mounted on a floor, wall or roof; and installed with or without vibration isolation.

Provisions

BUILDING CODE PROVISIONS

Seismic loads for transformers are determined using ASCE/SEI 7-10, *Minimum Design Loads for Buildings and Other Structures*, (ASCE, 2010), Chapter 13. The principal objective is to prevent the component from sliding or overturning. They may be floor mounted, wall mounted, or suspended from the level above.

- ASCE/SEI 7-10 requires anchorage design for all equipment in Seismic Design Categories D, E, and F if the equipment weighs over 400 pounds. Lighter components may be exempt if the component Importance Factor $I_p = 1.0$.
- Items that are exempt from the anchorage design requirements must still be positively anchored to the structure. The anchorage need not be designed or detailed on the construction documents. Exempt items must also be provided with flexible connections between the equipment and associated raceways, bus ducts, or conduits if there is a potential for damaging differential movement between the equipment and connected components.
- Internal coils of dry type transformers should be positively attached to their supporting substructure within the transformer enclosure.
- Electrical component supports and their attachment to the component must be designed for the appropriate forces and displacements. Supports include braces, frames, skirts, legs, pedestals, and snubbers, as well as elements forged or cast as a part of the mechanical or electrical component.
- The seismic design must consider the loads imposed on the components by attached utility or service lines that are attached to separate structures.
- Attachments for additional external items not provided by the manufacturer that weigh more than 100 lb should be evaluated.

RETROFIT STANDARD PROVISIONS

ASCE/SEI 41-06, *Seismic Rehabilitation of Existing Buildings*, (ASCE, 2007) classifies electrical equipment, including transformers, as force controlled. These components are subject to the provisions of the standard when the performance level is Immediate Occupancy. The requirements also apply when the performance level is Life Safety in high and moderate seismicity areas, and the equipment is over 6 feet in height and weighs more than 20 pounds. When applicable, electrical equipment meeting any of the following criteria must comply with the requirements of ASCE/SEI 41-06:

- The item weighs more than 400 pounds,
- The item is unanchored, weighs over 100 pounds and is subject to overturning. These items may be exempt if they have a factor of safety greater than 1.5 when design loads are applied.
- The item weighs over 20 pounds and is mounted over 4 feet above the floor.
- Building operation equipment.

Acceptance criteria for electrical equipment focus on providing adequate anchorage for seismic forces.

Typical Causes of Damage

- Transformers may slide, tilt, overturn, or fall. Vibration isolation hardware may be damaged.
- Internal elements may be damaged by inertial forces.
- Damaged electrical equipment may be cause electrical hazards and fire hazards. Transformer damage may result in power outages and business interruption.

DAMAGE EXAMPLES

Figure 6.4.7.3-1 Rail mounted transformer slipped off rails at power plant in Port-au-Prince in the 2010 magnitude-7 Haiti Earthquake; only one of six identical transformers was damaged (Photo courtesy of Eduardo Fierro, BFP Engineers).

Seismic Mitigation Considerations

- Working around electrical equipment can be extremely hazardous. Read the Electrical Danger Warning and Guidelines in Section 6.6.8 of this document before proceeding with any work.
- This type of equipment can be supplied with a structural steel base, shop welded brackets, or predrilled holes for base anchorage. For any new equipment, request items that can be supplied with seismic anchorage provisions.
- See Section 6.4.1.1 for additional base anchorage details. Refer to FEMA 413 *Installing Seismic Restraints for Electrical Equipment* (2004) for additional mounting configurations such as wall- and roof-mounting, or vibration isolation as well as general information on the seismic anchorage of electrical equipment.

Figure 6.4.7.3-2 Typical electrical distribution dry type transformer. Note the use of manufacturer supplied anchor locations on base channels. Post earthquake photo from the 2010 Haiti M 7.0 Earthquake (photos courtesy of Philip J. Caldwell).

Figure 6.4.7.3-3 High ampacity power busway routing power from generator paralleling switchgear to facility. Note use of lateral restraints in addition to gravity hanger. Supplied uninterrupted power to critical facility during the 2010 M 7.0 Haiti earthquake. (photos courtesy of Philip J. Caldwell)

Figure 6.4.7.3-4 Outdoor low voltage switchgear supplying incoming utility power to critical facility. Note equipment frame seismic anchorage load path is bolted at both equipment frame and pad with a continuous rigid load path. Post earthquake photo from the 2010 M 7.0 Haiti earthquake. (photos courtesy of Philip J. Caldwell)

Figure 6.4.7.3-5 Outdoor liquid type electrical power transformer which converts incoming medium voltage to 480 volt utilization voltage for critical facility. Note use of manufacturer supplied diagonal elements on cooling fin assembly to minimize dynamic loading on liquid filled fin assembly which contains numerous welded connections. Post earthquake photo from the 2010 M 7.0 Haiti Earthquake (photos courtesy of Philip J. Caldwell).

Figure 6.4.7.3-6 Battery room for central network cell phone carrier after 2010 M 7.0 Haiti Earthquake. Three-story building which contained the UPS (uninterruptable power supply) and battery room was newly constructed and suffered near collapse structural damage which required structural demolition and replacement. Note that high mass batteries with integral structural system was rigidly anchored and sustained no damage or loss of operation despite building structural system displacing enough to shear support columns. Cellular carrier representative advised that the central network support functionality was maintained during Earthquake (photos courtesy of Philip J. Caldwell).

Figure 6.4.7.3-7 Heat rejection mechanical units which provide cooling for servers in cellular carrier central network facility (left photo). Collapsing security wall during the 2010 M 7.0 Haiti Earthquake crushed these units and resulted cyclical total failure of the cellular network as the servers hit temperature limits, shut down, rebooted and heated up again. System stability was restored by replacing the damaged units with temporary ones (right photo). Example of how the reliability of a critical facility essential system is both dependent upon adequate seismic restraints and a location which is free of structural and nonstructural falling hazards (photos courtesy of Philip J. Caldwell).

Figure 6.4.7.3-8 Example of rugged equipment. Post earthquake photos of two different essential facilities which sustained significant structural damage during the 2010 M 7.0 Haiti Earthquake. Wall mounted electrical power distribution panels were undamaged and remained functional even though the walls they were mounted to were severely damaged during the earthquake (photos courtesy of Philip J. Caldwell).

Figure 6.4.7.3-9 Incoming power switchgear for critical facility anchored through base undamaged by the 2010 Haiti M 7.0 Earthquake. Visual inspection of equipment base channels did not reveal any structural damage or equipment displacement on concrete equipment pad. Similar equipment located nearby which did not have a rigid seismic restraint with a continuous load path shifted on its pad (photos courtesy of Philip J. Caldwell).

MITIGATION DETAILS

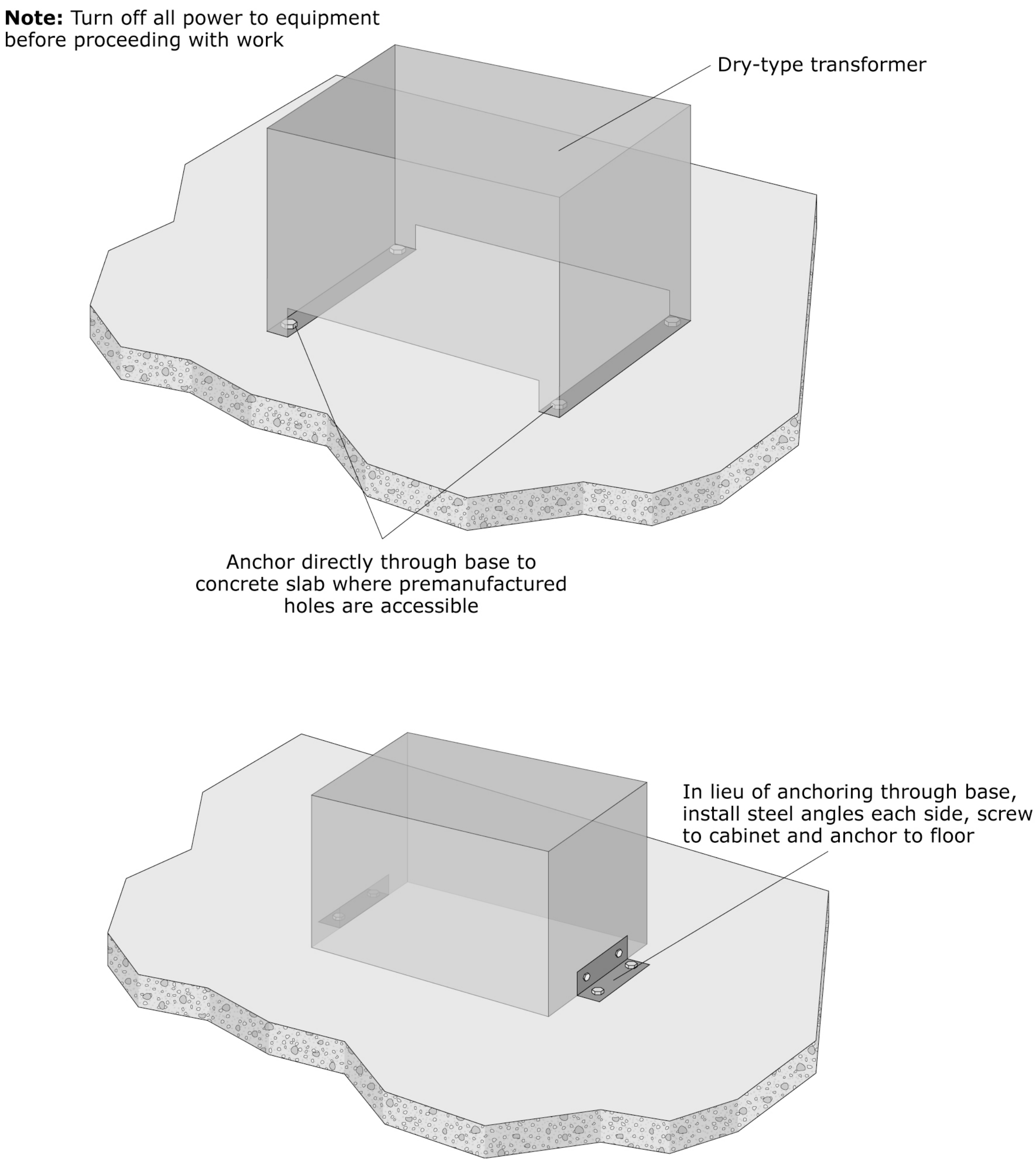

Figure 6.4.7.3-10 Transformer, note that external bracket must bolt directly to the internal frame to which the transformer core and coil assembly is attached (ER).