1.0 PURPOSE

This memorandum documents PG&E’s practice, preference and other criteria for design, detailing, and material specification of substation structures, equipment anchorage and foundations and pre-fabricated metal type control buildings. All plans and facility improvements shall conform to the applicable Federal, State, or local government regulations.

2.0 SCOPE

These criteria apply to structures, equipment anchorage and foundations supporting electrical equipment and overhead conductors and pre-fabricated metal type control buildings in electric substations, switching stations, and power plant switchyards; except those structures covered by the criteria for overhead electric transmission lines or by the project specific design criteria. The application of this DCM to specific projects shall be only as directed by the Responsible Civil Engineer.

The Responsible Civil Engineer shall obtain concurrence of Responsible Electrical Engineer on the suitability of a metal type control building for each specific installation.

3.0 GLOSSARY

Extreme Wind Load Area – Areas where one minute average wind speeds are 70 mph and above – based on PG&E’s Extreme Wind Map.

Fall Arrest System – The assemblage of equipment. These can include a line-worker's body belt, aerial belt, or full body harness in conjunction with a connecting means, with or without an energy absorbing device, and an anchorage on a structure or equipment.

Fall Restraint System – A system used to prevent a worker from falling. It consists of anchorages, connectors, and body belt/harness. It may include lanyards, lifelines, and rope grabs designed for that purpose.

Qualified Person – A person designated by the employer who by reason of training, experience or instruction has demonstrated the ability to safely perform all assigned duties and, when required, is properly licensed in accordance with federal, state, or local laws and regulations.

Responsible Civil Engineer – A California Registered Civil Engineer possessing a valid California Professional Civil Engineering license working in SED Civil Engineering.

Responsible Electrical Engineer – An electrical engineer working in SED Electrical Engineering.

SED Civil Engineering – Civil Engineering group within the Substation Engineering Department.

SED Electrical Engineering – Electrical Engineering group within the Substation Engineering Department.

Seismic Report – A report prepared by a qualified specialist who is competent in the seismic analysis and qualification of electrical equipment and/or it’s supporting structure and anchorage in accordance with IEEE Standard 693.

Shall – Indicates a mandatory requirement unless it is demonstrated impracticable.

Should – Indicates a recommended action.

UBC – Uniform Building Code. (This refers to requirements of the UBC as adopted or modified by the local authority having jurisdiction)

Work Positioning Device System – A body belt or body harness system rigged to allow a worker to be supported on an elevated surface, such as a wall, and work with both hands free while leaning.
4.0 DESIGN CRITERIA

4.1 General

4.1.1 Materials

Adhesive Anchors: ICBO-qualified adhesive anchors
Anchor Bolts: ASTM A307, A193/A193M or other ductile bolts, and anchor bolts from reinforcing bar stock conforming to ASTM A615, Grade 75
Concrete: 3,000 psi at 28 days
Connection Bolts: ASTM A307, A325, or A394
Reinforcing Steel: ASTM 615, Gr. 60
Steel Pipes: ASTM A53 Grade B
Structural Steel: ASTM A36 and ASTM A572
Structural Tubes: ASTM A500 Grade B

4.1.2 Steel Finish.

All structural members shall be hot-dip galvanized on all sides (both inside and outside for tubular members) except that any single member that cannot be single-dip galvanized shall be painted or metallized.

All bolts shall be galvanized regardless of surface coating of the structure.

Anchor bolts shall be galvanized. The galvanized dimension shall be the projecting portion plus at least 6 inches.

1. Galvanizing

Galvanizing shall be performed after fabrication in accordance with the recommendations of the American Galvanizers Association and in conformance with ASTM A123/123M for structural sections and ASTM B695 for bolts. Requirements include but are not limited to the following:

• Leave no area open to pickling acid into which galvanizing zinc cannot also reach.
• Sealed areas shall be minimized. Design openings at each end of the structural member cap or base plates to allow zinc to go through the interior of hollow sections. Openings shall be at least 30 percent of the cross-sectional area of the member.

2. Painting

Interior portions of members to be painted shall be sealed. Areas that are accessible by hand may be left open and hand painted.

3. Metallizing

Detailing requirements for structures to be metallized shall be similar to painted members. Metallizing shall be in accordance with the recommendations of AWS C2.2.

4.1.3 Concrete Finish

All exposed edges shall be chamfered. Surfaces on exterior slabs shall have medium broom finish. Interior slabs shall be finished with a steel trowel or a light broom finish.
4.2 Loads and Load Combinations

4.2.1 Static Loads (D)
Static load shall include the weight of structure and, as specified by the manufacturer or Responsible Electrical Engineer, the weight of equipment, insulators, and conductors (including line loads due to line tension and weight of the conductor).

4.2.2 Transient Loads
1. Wind Load (W)
   a) Wind load on equipment and supporting structures shall be calculated based on the requirements of NESC. Except for wind loading for dead-end structures detailed in Section 4.2.4, wind load shall be calculated as follows:

   \[ W = 0.00256 \times K_z \times V^2 \times G_{RF} \times C_d \]

   where:

   - \( W \) = Load in pounds per square foot,
   - 0.00256 = Ambient Air Density Value, reflecting the mass density of air for the standard atmosphere, i.e., temperature of 59 °F and sea level pressure of 29.92 inch of mercury,
   - \( K_z \) = 1.0 Velocity Pressure Exposure Coefficient, for height less than 50 feet, as defined in NESC Rule 250C1, Table 250-2,
   - \( V \) = 85 mph 3-second gust Basic Wind Speed, based on NESC 250-2 (a) or PG&E's Extreme Wind Map (http://gisweb.comp.pge.com/gis/). A factor of 1.2 shall be used to convert the 1-minute average wind speed value from PG&E's extreme wind map to a 3-second gust value,
   - \( G_{RF} \) = 0.97 Gust Response Factor, as defined in NESC Rule 250C2,
   - \( C_d \) = Shape Factor, as defined in NESC Rule 252B
     - = 1.0 for cylindrical structures and components
     - = 1.6 for flat surfaced solid structures and components
     - = 3.2 for lattice structures (on the sum of the projected areas of the members of the front face if structural members are flat surfaced; the total not exceeding the load that would occur on a solid structure of the same outside dimension).

   In lieu of determining site and structure specific wind loads, the following values of \( W \) may be used for design:

   - \( W = 17.9 \) psf for cylindrical structures and components
   - \( W = 28.7 \) psf for flat surfaced solid structures and components, and for lattice structures based on the front-face gross area (boundaries)

   b) Wind load on control buildings shall conform to Exposure C described in the UBC, with 80 mph basic wind speed, and \( I = 1.15 \), unless specified by the Responsible Civil Engineer.
2. Operating Load (OP)

Use load specified by the equipment manufacturer. For oil circuit breakers, if the manufacturer specifies no operating load use \( \pm 2D \) vertically. Due to the short duration of circuit breaker operating loads, use these loads only for the design of equipment anchorage.

3. Short Circuit Load (S)

Use the method for computing short circuit forces provided by DCM C-1.4.

4. Seismic Load (E)

SED Responsible Civil and Electrical Engineers shall determine if equipment and supporting structures require seismic qualification. See Attachment 2 to this DCM.

a) Structures requiring seismic qualification shall be designed based upon the seismic report.

b) Structures not requiring seismic qualification shall be designed using the seismic coefficient and application tables below.

c) All foundations shall be designed using the seismic coefficient and application tables below.

d) Anchorage for structures requiring seismic qualification shall be designed based upon the seismic report, or in a manner consistent with the structure design.

e) For control buildings and firewalls, seismic loading shall conform to Zone 4 requirements of the UBC unless specified by the Responsible Civil Engineer.

<table>
<thead>
<tr>
<th></th>
<th>High Seismic Zone Coefficients</th>
<th>Moderate Seismic Zone Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Structures Horizontal Vertical</td>
<td>Structures Horizontal Vertical</td>
</tr>
<tr>
<td>Flexible</td>
<td>0.75D</td>
<td>0.41D</td>
</tr>
<tr>
<td>Rigid (fundamental period less than or equal to 0.06 second)</td>
<td>0.46D</td>
<td>0.25D</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.33D</td>
</tr>
</tbody>
</table>

**Application**

- **Horizontal**
  Through the center of gravity of the component or equipment being considered. If the center of gravity of the equipment being considered is not available, apply the horizontal load at 2/3 of the height of the equipment (H). The direction shall be transverse or longitudinal or any combination which produces the greater stress.

- **Vertical**
  Through the center of gravity of the component or equipment being considered.
PH = Horizontal seismic coefficient x D
PV = Vertical seismic coefficient x D
D = Dead load
H = Height of equipment
C.G. = Center of gravity

Where appropriate, the Responsible Civil Engineer shall specify higher seismic loads for equipment mounted on a structure.

5. Ice (I)

Ice loading shall be based upon local geographic conditions in conjunction with data provided by ASCE 7.

4.2.3 Load Combinations

1. Combining Nominal Loads Using Allowable Stress Design (ASD)

D + OP
D + I + 0.4W
D + S + 0.4W
D + 0.7E*  

*For equipment requiring seismic qualification, the load 0.7E shall be replaced by the earthquake demand load defined by the seismic qualification report.

2. Combining Factored Loads Using Load Factor/Strength Design (LRFD)

1.4 (D + OP)
1.2D + 1.6I + 0.8W
1.2(D + S) + 0.7W
0.9D ± (1.0E or 1.6W)
4.2.4 Special Loading Conditions for Dead-end Structures

In addition to wind loads on the structure itself calculated per section 4.2.2.1, dead-end structures shall be designed for the following conductor loading conditions:

For longitudinal loading (horizontal loads perpendicular to the dead-end structure beam), consider electrical conductor loads pulling off from one direction only (ahead or back of structure):

For transverse loading (horizontal loads parallel to the dead-end structure beam), consider electrical conductor loads pulling off in both directions (ahead and back of structure) at a 60° total line angle.

Conductor line tensions provided by the Responsible Electrical Engineer shall as a minimum include the effects of dead, wind, ice and temperature loads specified in G.O. 95 as given below. The minimum ASD safety factor shall be 1.5 for Light, Moderate, and Heavy Loading Areas, and 1.0 for the Extreme Wind Loading Area.

Light Loading Area – For elevation 1500 ft and below.

Wind – Apply 8 psf horizontal wind pressure on cylindrical surfaces, and 13 psf on flat surfaces. For latticed structure, the exposed area of the front face shall be increased by 50% to account for the pressure on the back face, provided it does not result in a greater pressure than a solid structure of the same outside dimensions.

Ice – No ice loading shall be considered.

Temperature – 25°F at maximum loading.

Dead load – Weight of structure, conductors, insulators, and equipment.
Intermediate Loading Area – For elevation above 1500 ft to 3000 ft.

Wind – Apply 6 psf horizontal wind pressure on cylindrical surfaces, and 10 psf on flat surfaces. For latticed structure, the exposed area of the front face shall be increased by 50% to account for the pressure on the back face, provided it does not result in a greater pressure than a solid structure of the same outside dimensions.

Ice – ¼ inch radial ice, weighing 57 pcf, on all conductors.

Temperature – 0°F at maximum loading.

Dead Load – Weight of structure, conductors, insulators, and equipment.

Heavy Loading Area – For elevation exceeding 3000 ft.

Wind – Apply 6 psf horizontal wind pressure on cylindrical surfaces, and 10 psf on flat surfaces. For latticed structure, the exposed area of the front face shall be increased by 50% to account for the pressure on the back face, provided it does not result in a greater pressure than a solid structure of the same outside dimensions.

Ice – ½ inch radial ice, weighing 57 pcf, on all conductors.

Temperature – 0°F at maximum loading.

Dead Load – Weight of structure, conductors, insulators, and equipment.

Extreme Wind Loading Area

Wind speed under this category shall be based on PG&E’s Extreme Wind Map (http://gisweb.comp.pge.com/gis/). A factor of 1.2 shall be used to convert the 1-minute average wind speed value from PG&E’s extreme wind map to a 3-second gust value. Wind pressure for conductors, as indicated below, shall be calculated according to NESC based on 3-second gust wind speed and applied in any direction to the structure under the actual intact wire condition.

Wind Pressure in psf = 0.00256 $K_z \cdot V^2 \cdot G_{RF} \cdot C_d$

Using Exposure C for open terrain, design equations are as follows:

$$K_z = 2.01 \left( \frac{h}{900} \right)^{2.9.5}$$

$h = $ Wire height per NESC Rule 250C2, in feet

$V = $ Basic wind speed in 3-second gust

$G_{RF}$ (Wire) = $\left( 1 + 2.7 \left( \frac{E_w}{w} \right)^{0.5} \right) / \left( K_v \right)^2$

$E_w = 0.346 \left( \frac{33}{h} \right)^{1/7}$

$B_w = 1 / \left( 1 + 0.8 \left( \frac{L}{220} \right) \right)$

$K_v = 1.43$

$L = $ Wind span of wire, in feet

$C_d$ (Wire) = 1.0

4.2.5 Fall Protection Anchorage Loads

When an engineering evaluation is needed to determine an existing fall arrest anchor point capacity, or when a new anchor point must be designed, a Qualified Person shall prepare or oversee the evaluation/design.

Fall Arrest Systems: Anchorages used for attachment of personal fall arrest equipment shall be independent of any anchorage being used to support or suspend platforms, and shall have a minimum ultimate capacity of 5,000 pounds per employee attached. Alternatively, these anchorages may be designed and installed as part of a complete personal fall arrest system, which requires a safety factor of at least 2.0. However, the design of fall arrest anchorage for specific equipment is discouraged unless the Responsible Civil Engineer can be assured that only the specific type of equipment used to develop the design will be attached to the anchorage.
Fall Restraint Systems: Anchorage points for fall restraint systems shall have a minimum ultimate capacity of four times the intended load.

Work Positioning Device System: Anchorage points for work positioning device systems shall have a minimum ultimate capacity of two times the intended load or 3,000 pounds, whichever is greater.

4.3 Stresses

4.3.1 Structural Steel

Structural steel elements shall be designed in accordance with the AISC Manual of Steel Construction – Load Resistance Factor Design (LRFD) or alternatively Allowable Stress Design (ASD). For ASD design only, allowable stresses for seismic load combinations may be increased by a factor of 1.33, except connection and anchorage element allowable stresses shall not be increased.

4.3.2 Reinforced Concrete

Reinforced concrete elements shall be designed in accordance with strength design provisions of ACI 318.

4.3.3 Soil Resistance

Allowable Soil Pressures shall be determined by a soils study performed under the direction of a Geotechnical Engineer or as specified by the Responsible Civil Engineer.

Existing Substations: Where spread foundations or augered footings have performed satisfactorily in existing substations, the pressures recommended in the soils report for that substation shall be used. If no soils report exists, the values listed in the following sections may be used when specifically approved by the Responsible Civil Engineer.

1. Spread Foundations:

   Vertical:
   - Static loads: 2,000 lb/ft².
   - Static combined with wind, seismic, or short circuit loading: 4,000 lb/ft².

   Lateral:
   - Design using a passive resistance of 200 lb/ft². This value may be increased by 200 lb/ft² for each additional foot of depth greater than one foot below grade to a maximum of 3,000 lb/ft². For transient loads, use soil to concrete coefficient of friction of 0.5.

2. Augered Footing:

   Vertical Bearing:
   
   \[ f_b = 4 + 0.2 (E - 1) \leq 8 \text{ ksf} \]

   Where:
   - \( f_b \) = Allowable vertical bearing stress (ksf)
   - \( E \) = Embedment depth in feet

   Lateral Bearing:

   Use values shown in the Recommended Lateral Soil Pressure Table in Sheet 2 of Attachment 1, based on site soil conditions or 500 psf per foot of depth. Augered footing may be designed using the Augered Footings Design Chart in Sheet 1 of Attachment 1 based on ASD load combinations.
Pullout:
Where augered footings undercut adjacent soils, the weight of soil contained in an inverted cone, with sides 30° from vertical, may be considered to resist pullout. Neglect friction and cohesion.

3. Pile Footing
Site-specific design criteria shall be provided by the Responsible Civil Engineer.

4.3.4 Adhesive Anchors
Adhesive anchors shall be designed using allowable forces published in ICBO Evaluation Reports. These allowable forces may be increased by 1.4 when using Ultimate Strength Design.

4.4 Design

4.4.1 Structure Details
1. Beams
   - The cantilevered end of rectangular steel tubing beams should have removable closure plates to facilitate galvanizing.
   - On dead-end structures, pull off plates for line termination attachment on both ahead and back spans, shall have round edged holes.
   - Bolt holes shall be 1/16-inch oversize in flat or single thickness material.

2. Columns
   - Cap plates for rectangular steel tubing, and base plates should be fabricated from flat steel plates.
   - Tubular Dead-end structures should be fabricated from tapered steel sections.

4.4.2 Control Buildings
1. Structural design shall conform to the UBC. Alternative design criteria may be specified by the Responsible Civil Engineer if required by the local Building Official, provided that the intent of this DCM is satisfied.

2. The structural design of panels used as part of the lateral-load-resisting system of the building (e.g., roof diaphragms and shear walls) shall be supported by ICBO Evaluation Reports. Design details shall be consistent with those specified in the corresponding ICBO Evaluation Report.

3. Openings: Openings in structural panels and members shall be considered in the design. When required by analysis, openings shall be reinforced, or alternative mechanisms of resistance (such as bracing) shall be provided.

4. Anchoring systems (e.g., expansion anchors, epoxy adhesive anchors) used for structural purposes shall be designed in accordance with, and supported by ICBO Evaluation Reports.
5. Structural design calculations shall be furnished by the supplier of the pre-fabricated metal building. Calculations shall include the following:

a. Determination of design loading
b. Identification of the load paths for lateral and vertical loads
c. Evaluation of critical members
d. Evaluation of critical connections
e. Evaluation of building anchorage
f. ICBO Evaluation Reports supporting the shear panel designs and anchorage systems used.

4.4.3 Deflections

The following limitations shall be calculated using ASD load combinations:

1. Structural deflections shall meet the requirements of this section under combined dead loads, operating loads and wind loads. If the equipment manufacturer’s deflection limit is more stringent than the requirements of this section, the manufacturer’s limit shall govern.

2. For structures supporting equipment with mechanical mechanisms where structural deflections could impair proper operation, the vertical or horizontal deflection of horizontal members shall not exceed 1/200 of the span. Horizontal deflections of vertical members shall not exceed 1/100 of the height. Examples include supports for group-operated switches, vertical reach switches, ground switches, and circuit interrupting devices.

3. For structures supporting equipment without mechanical mechanisms but where excessive deflection could result in compromised phase-to-phase or phase-to-ground clearances, or unpredicted stresses in equipment, fittings or bus, the vertical deflection of horizontal members shall not exceed 1/200 of the span and the horizontal deflections of horizontal members shall not exceed 1/100 of the span. Horizontal deflections of vertical members shall not exceed 1/100 of the height. Examples include supports for rigid bus, lightning/surge arrestors, metering devices such as CT’s, PT’s, and CCVT’s, station power transformers, hot-stick operated switches, air core reactors, and line/wave traps.

4. For structures supporting equipment that is relatively insensitive to deflections, or stand-alone structures that do not support any equipment, the vertical or horizontal deflection of horizontal members shall not exceed 1/100 of the span. Horizontal deflections of vertical members shall not exceed 1/50 of the height. Examples include supports for stranded flexible conductors including dead end structures, and masts for lightning shielding.

4.4.4 Anchor Bolts and Other Attachments

1. On Equipment Foundations:

The method of anchoring transformers, regulators, and transmission voltage (60 kV or greater) circuit breakers to foundations should be by welding, in accordance with AWS D1.1, to rolled steel sections or insert plates embedded in concrete. Distribution voltage (less than 60kV) circuit breakers shall be anchored to foundations with adhesive anchors unless otherwise directed by the Responsible Civil Engineer.

Embeds in concrete, such as insert plates and anchor bolts shall be designed such that the capacity of the steel elements can be developed before concrete failure. ACI 349 or a similar rational method may be used.

Adhesive anchors are preferred over expansion anchors. Exceptions are cases in which adhesive anchors are expected to resist gravity loads concurrent with fire or other degrading environmental effects.
2. On Augered Footings for Structures:

   Recommended anchor bolt diameters are 1/2" to 2 1/4" at 1/4" increments.
   Use threaded straight plain or reinforcing bar bolts with two or three heavy hexagonal nuts above the concrete (one or two to secure, the other to level the structure) and one at the embedded end for anchoring. The bolt threads at the embedded end of the bolt shall be spoiled at two places below the nut. When specifying projection length, accommodate room required for the leveling nuts, the base plate, the security nuts and an extension (equivalent to one bolt diameter) for bolts that may be set too low in the field. Also, specify extra threaded length to accommodate bolts set too high.

4.4.5 Foundations

1. Structure foundations shall be designed for the static plus transient loads of the structure and its supported equipment in accordance with ACI 318.

2. For transient load combinations using ASD, except earthquake, the factor of safety against both sliding and overturning shall be at least 1.5 (i.e., the equipment/foundation system remains stable when subjected to Static Load + 1.5 x Transient Load). Factor of safety against sliding and overturning for earthquake loads shall be greater than 1.0.

3. Transformer foundations shall be 1'-0" or greater in thickness with two layers of reinforcing.

4. Augered footing diameters should be a minimum 2'-0" increasing at 6" increments.

5. Recommended reinforcing vertical bar sizes are #5, #6, #8, or #10 - arranged to transfer bond from the anchor bolts, and tied with #3 or #4 bars. There should be at least 3 ties, spaced at 3" apart near the top of the footing.

6. Spread footing reinforcing bar sizes shall be #4, #5, #6, #8, or #10.

7. Seismic Design:

   Sliding: Exclude the mass of the concrete foundation when calculating the lateral sliding forces, but include the mass of the concrete foundation when calculating the resisting frictional forces.

   Overturning: Exclude the mass of the concrete foundation when calculating the overturning forces, but include the mass of the concrete foundation when determining the forces that resist overturning of the equipment/foundation system.
5.0 CODES, STANDARDS, and REFERENCES

Note: All codes and standards listed shall be the revision in effect at the time design is approved for construction.

1. ACI 318/318R – Building Code Requirements for Structural Concrete and Commentary
2. ACI 349/349R – Code Requirements for Nuclear Safety Related Concrete Structures and Commentary
3. American Galvanizers Association
4. AISC – Manual of Steel Construction – Load Resistance Factor Design (LRFD) and Allowable Stress Design (ASD)
5. AISI – American Iron and Steel Institute – Cold-Formed Steel Design Manual
6. ASCE 7 – American Society of Civil Engineers – Minimum Design Loads for Buildings and Other Structures
7. ASTM A36/A36M – Standard Specification for Carbon Structural Steel
8. ASTM A53/A53M – Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
13. ASTM A394 – Standard Specification for Steel Transmission Tower Bolts, Zinc-Coated and Bare
14. ASTM A500 – Standard Specification for Cold-Formed Welded and Seamless Carbon Steel Structural Tubing in Rounds and Shapes
15. ASTM A572/A572M – Standard Specification for High-Strength Low-Alloy Columbium-Vanadium Structural Steel
16. ASTM A615/A615M – Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement
18. AWS C2.23M/C2.23 – Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and their Alloys and Composites for the Corrosion Protection of Steel
19. AWS D1.1 – Structural Welding Code – Steel, American Welding Society
20. CBC – California Building Code
22. ICBO – ER-5279 – International Conference of Building Officials Evaluation Report, Fasteners – Concrete and Masonry Anchors
23. IEEE 693 – Recommended Practices for Seismic Design of Substations, Institute of Electrical and Electronic Engineers
24. NESC – National Electric Safety Code, Institute of Electrical and Electronics Engineers
25. OSHA – Occupational Safety and Health Administration

6.0 ATTACHMENTS
2. Equipment and Structures Requiring Seismic Qualification
3. Design Process For Structures, Anchorages and Foundations
AUGERED FOOTINGS DESIGN CHART

Example

SF = 1.5 included

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RECOMMENDED LATERAL SOIL PRESSURE (Q) TABLE
POUNDS PER SQ/FT PER FOOT OF DEPTH

<table>
<thead>
<tr>
<th>SOIL DESCRIPTION</th>
<th>ALLOWABLE MOTION AT GROUND SURFACE (IN)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1/16&quot;</td>
</tr>
<tr>
<td>MEDIUM HARD CALICHE</td>
<td>500</td>
</tr>
<tr>
<td>FINE CALICHE WITH SAND LAYERS</td>
<td>400</td>
</tr>
<tr>
<td>COMPACT WELL GRADED GRAVEL</td>
<td></td>
</tr>
<tr>
<td>MEDIUM DENSE CLAY</td>
<td>350</td>
</tr>
<tr>
<td>COMPACT COARSE SAND</td>
<td>300</td>
</tr>
<tr>
<td>COMPACT COARSE &amp; FINE SAND</td>
<td></td>
</tr>
<tr>
<td>MEDIUM STIFF CLAY</td>
<td></td>
</tr>
<tr>
<td>COMPACT FINE SAND</td>
<td>250</td>
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<tr>
<td>ORDINARY SILT</td>
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</tr>
<tr>
<td>SANDY CLAY</td>
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<tr>
<td>ADOBE</td>
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<tr>
<td>COMPACT INORGANIC SAND &amp; SILT MIXTURES</td>
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<tr>
<td>SOFT CLAY</td>
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</tr>
<tr>
<td>LOOSE ORGANIC SAND &amp; SILT MIXTURES; MUCK OR BAY MUD</td>
<td>0</td>
</tr>
</tbody>
</table>

THE REQUIRED EMBEDMENT IS OBTAINED FORM THE INTERSECTION OF THE CURVE Q FOR ALLOWABLE LATERAL SOIL BEARING WITH A STRAIGHT LINE DRAWN FROM H₀ TO M₀:

\[ L^3 - 9 \times H_0 \times L/Q - 12xM_0/Q = 0 \]

EXAMPLE:

GIVEN:
- 2'-6" DIAMETER AUGERED FOOTING AND ALLOWABLE LATERAL BEARING Q = 500 psf per ft of depth
- LATERAL FORCE, H = 5 kips
- MOMENT AT GROUND SURFACE, M = 50 + (20x1.25) = 75 k-ft
- \( H_0 = 5/2.5 = 2 \) kips per ft of width
- \( M_0 = 75/2.5 = 30 \) k-ft per ft of width

SOLUTION:
- DRAW A LINE FROM \( H_0 = 2 \) TO \( M_0 = 30 \) AT POINT OF INTERSECTION WITH CURVE FOR Q = 500 #/ft²
- READ L IN HORIZONTAL SCALE

ANSWER:
- L = 10.3 feet
**ATTACHMENT 2**

**EQUIPMENT AND STRUCTURES REQUIRING SEISMIC QUALIFICATION**

This attachment identifies which electric substation equipment and structures require seismic qualification. Requests for clarification should be directed to the Substation Engineering Department. Seismic qualification requirements for equipment shall be as stated in IEEE 693 except as noted. Equipment may be procured to a higher standard than stated below. Equipment procured to IEEE 693 shall be supported in a manner consistent with the qualification report.

<table>
<thead>
<tr>
<th>Equipment/Structure</th>
<th>Qualification Required?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air Core Reactor and support structure</td>
<td>Y</td>
</tr>
<tr>
<td>Air Switch</td>
<td>Y</td>
</tr>
<tr>
<td>Batteries and Supporting Rack</td>
<td>Y</td>
</tr>
<tr>
<td>Bus Support</td>
<td>N</td>
</tr>
<tr>
<td>Capacitor Bank</td>
<td>Y</td>
</tr>
<tr>
<td>CCVT, CT, PT</td>
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</tr>
<tr>
<td>Circuit Breaker &lt; 60kV</td>
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<tr>
<td>Circuit Breaker, ≥ 60kV</td>
<td>Y</td>
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<tr>
<td>Circuit Switcher</td>
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<tr>
<td>Dead-end Structures</td>
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<tr>
<td>Elevated structure for air switch</td>
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<tr>
<td>Low-profile support structure for air switch</td>
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<tr>
<td>Metalclad Switchgear</td>
<td>Y</td>
</tr>
<tr>
<td>Regulators</td>
<td>Y</td>
</tr>
<tr>
<td>Station Service Transformer</td>
<td>N</td>
</tr>
<tr>
<td>Substation Control Equipment and supporting rack</td>
<td>Y</td>
</tr>
<tr>
<td>Surge Arrester and supporting structure</td>
<td>N</td>
</tr>
<tr>
<td>Transformer</td>
<td>Y</td>
</tr>
<tr>
<td>Wave Trap</td>
<td>N</td>
</tr>
</tbody>
</table>
ATTACHMENT 3

DESIGN PROCESS FOR STRUCTURES, ANCHORAGES AND FOUNDATIONS

This figure is intended to provide an overview of the design process, and does not include all steps needed to produce a design.

2. Check IEEE 693 Seismic Qualification Requirement?
   - If No, design to ASD?
     - If Yes, create ASD load combinations from seismic qualification report.
     - If No, create factored strength design load combinations per DCM Section 4.2.
   - If Yes, create ASD load combinations per DCM Section 4.2. Reduce DCM seismic load by 1.4 factor.
3. Design structure to IEEE 693 requirements for seismic, DCM Section 4.2 for other loads.
4. Design connections and anchorages per seismic qualification report requirements.
5. Design anchorages for ductile behavior/structure capacity.
6. Design foundation per DCM Sections 4.4.4 & 4.4.5—Use USD for reinforced concrete, ASD for soil pressure.

**Note**
- ASD = Allowable Stress
- USD = Load Factor
- Design

**Symbols**
- ASD = Allowable Stress
- USD = Load Factor