



ACCEPTANCE CRITERIA FOR HELICAL FOUNDATION SYSTEMS AND DEVICES

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PREFACE

Evaluation reports issued by ICC Evaluation Service, Inc. (ICC-ES), are based upon performance features of the International family of codes and other widely adopted code families, including the Uniform Codes, the BOCA National Codes, and the SBCCI Standard Codes. Section 104.11 of the *International Building Code*[®] reads as follows:

The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Similar provisions are contained in the Uniform Codes, the National Codes, and the Standard Codes.

This acceptance criteria has been issued to provide all interested parties with guidelines for demonstrating compliance with performance features of the applicable code(s) referenced in the acceptance criteria. The criteria was developed and adopted following public hearings conducted by the ICC-ES Evaluation Committee, and is effective on the date shown above. All reports issued or reissued on or after the effective date must comply with this criteria, while reports issued prior to this date may be in compliance with this criteria or with the previous edition. If the criteria is an updated version from the previous edition, a solid vertical line (|) in the margin within the criteria indicates a technical change, addition, or deletion from the previous edition. A deletion indicator (→) is provided in the margin where a paragraph has been deleted if the deletion involved a technical change. This criteria may be further revised as the need dictates.

ICC-ES may consider alternate criteria, provided the report applicant submits valid data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria set forth in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise demonstrate compliance with the performance features of the codes, ICC-ES retains the right to refuse to issue or renew an evaluation report, if the product, material, or type or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use of the product, material, or type or method of construction.

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1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for helical foundation systems and helical foundation devices to be recognized in ICC Evaluation Service, Inc. (ICC-ES), evaluation reports under the 2006 *International Building Code*[®] (IBC) and the 1997 *Uniform Building Code*[™] (UBC). Bases for recognition are IBC Section 104.11 and UBC Section 104.2.8.

The reason for the development of this acceptance criteria is to supplement general requirements for pile foundations in the IBC and UBC to permit evaluation of helical foundation systems and devices.

1.2 Scope: This criteria provides methods to establish the allowable load and deformation capacities of helical foundation systems and devices used to resist axial compression, axial tension or lateral loads. This criteria applies to helical foundation systems and devices as defined in Section 1.4 and includes provisions for determining soil embedment and soil capacity.

This criteria is limited to helical foundation systems and devices used under the following conditions:

1.2.1 Support of structures in IBC Seismic Design Categories A, B, or C, or UBC Seismic Zones 0, 1 or 2, only.

1.2.2 Exposure conditions to soil that are not indicative of potential pile deterioration or corrosion situations as defined by the following: (1) soil resistivity less than 1,000 ohm-cm; (2) soil pH less than 5.5; (3) soils with high organic content; (4) soil sulfate concentrations greater than 1,000 ppm; (5) soils located in landfills, or (6) soil containing mine waste.

1.2.3 Helical products manufactured from carbon steel, with optional zinc or powder coatings.

1.3 Codes and Referenced Standards: Where standards are referenced in this criteria, these standards shall be applied consistently with the code (IBC, and UBC) upon which compliance is based in accordance with Table 1.

1.3.1 2006 *International Building Code*[®] (IBC), International Code Council.

1.3.2 1997 *Uniform Building Code* (UBC)[™].

1.3.3 ICC-ES Acceptance Criteria for Inspection Agencies (AC304).

1.3.4 ANSI/AF&PA NDS, National Design Specification for Wood Construction (NDS), American Forest & Paper Association.

1.3.5 ACI 318-05, Building Code Requirements for Structural Concrete, American Concrete Institute.

1.3.6 Specification for Structural Steel Buildings, Load and Resistance Factor Design, 3rd Edition, American Institute of Steel Construction (AISC LRFD).

1.3.7 Specification for Structural Steel Buildings, Allowable Stress Design, American Institute of Steel Construction (AISC ASD).

1.3.8 ANSI/ASME Standard B18.2.1-1996, Square and Hex Bolts and Screws, Inch Series, American Society of Mechanical Engineers.

1.3.9 ANSI/AWS D1.1/D1.1M, Structural Welding Code—Steel (AWS D1.1/D1.1M), American Welding Society.

1.3.10 ASTM A 123-02, Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products, ASTM International.

1.3.11 ASTM A 153-05, Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware, ASTM International.

1.3.12 ASTM B 633-07 Standard Specification for Electro deposited Coatings of Zinc on Iron and Steel, ASTM International.

1.3.13 ASTM B 695-04 Standard Specification for Coatings of Zinc Mechanically Deposited on Iron and Steel, ASTM International.

1.3.14 ASTM C 31-98, Standard Practice for Making and Curing Concrete Test Specimens in the Field, ASTM International.

1.3.15 ASTM C 39-03, Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens, ASTM International.

1.3.16 ASTM D 1143-81(1994)e1, Standard Test Method for Piles Under Static Axial Compressive Load, ASTM International.

1.3.17 ASTM D 1586-99, Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils, ASTM International.

1.3.18 ASTM D 3689-90(1995), Standard Test Method for Individual Piles under Static Axial Tensile Load, ASTM International.

1.3.19 ASTM D 3966-90(1995), Standard Test Method for Piles under Lateral Loads, ASTM International.

1.3.20 ICC-ES Acceptance Criteria for Corrosion Protection of Steel Foundation Systems Using Polymer (EAA) Coatings (AC228).

1.4 Definitions: Terminology herein is based on the Glossary of the AISC LRFD and the following definitions:

1.4.1 Angle Bracket: A side load bracket with horizontal bearing plate extending below and supporting a concrete foundation.

1.4.2 Helical Foundation System: A factory-manufactured steel foundation designed to resist axial compression, axial tension, and/or lateral loads from structures, consisting of a central shaft with one or more helical-shaped bearing plates, extension shafts, and a bracket that allow for attachment to structures. The shafts with helix bearing plates are screwed into the ground by application of torsion and the shaft is extended until a desired depth or a suitable soil or bedrock bearing stratum is reached.

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1.4.3 Helical Foundation Device: For purposes of this criteria, a helical foundation device is any part or component of a helical foundation system.

1.4.4 Lateral Resistance: Capacity of a helical foundation system or device to resist forces acting in a direction that is perpendicular to the longitudinal direction of the shaft.

1.4.5 Conventional Design: Methods for determining design capacities of the helical foundation system that are prescribed by and strictly in accordance with standards and codes referenced in Section 1.3.

1.4.6 Special Analysis: Methods for determining design capacities of the helical foundation system that incorporate finite element modeling, discrete element modeling, strain compatibility, or other conventional analytical/numerical techniques. Computer software developed for the analysis of laterally loaded piles, which incorporate methods of analysis considering the nonlinear interaction of the shaft with soil, is an example of special analysis.

2.0 BASIC INFORMATION

2.1 General: The following information shall be submitted with ICC-ES evaluation report applications:

2.1.1 Summary Document: A tabulated list of the helical foundation systems, devices, and combinations thereof to be included in the ICC-ES evaluation report, along with proposed structural capacities. All systems and devices shall be clearly identified in the documentation with distinct product names and/or product numbering.

2.1.2 Product Description: Helical products shall be manufactured from carbon steel, with optional zinc or powder coatings. Complete information pertaining to the helical foundation systems or devices, including material specifications and drawings showing all dimensions and tolerances, and the manufacturing processes. All materials, welding processes and manufacturing procedures used in helical foundation systems and devices shall be specified and described in quality documentation complying with Section 5.2. All material specifications shall comply with ASTM, ACI, NDS, AISC, UBC, or IBC requirements. Material composition, grade, and sizes of bolts and fasteners shall be based on criteria in AISC, ASTM, or ANSI requirements.

2.1.3 Installation Instructions: Procedures and details regarding helical foundation system or device installation, including product-specific requirements, exclusions, limitations, and inspection requirements, as applicable.

2.1.4 Packaging and Identification: A description of the method of packaging and field identification of each helical foundation system device. Identification provisions shall include the manufacturer's name and address, product name and model number, evaluation report number and name or logo of the inspection agency.

2.1.5 Design Calculations: Clear and comprehensive calculations of ASD or LRFD structural capacities for system or device, based on requirements of the IBC or UBC and this criteria. Calculations shall be sealed by a registered design professional.

2.2 Testing Laboratories: Testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.3 Test Reports: Reports of tests required under Section 3.0 of this criteria shall comply with AC85 and reporting requirements in referenced standards.

2.4 Product Sampling: Sampling of devices for tests under this criteria shall comply with Section 3.1 of AC85.

3.0 DESIGN, TEST, AND PERFORMANCE REQUIREMENTS

3.1 General: The helical foundation systems and devices shall be evaluated for resistance to axial compression, axial tension, or lateral loads, or a combination of these loads. The required capacities shall be evaluated by considering four primary structural elements of the helical foundation system as shown in Figures 1 through 4. These elements are described as Bracket Capacity (P1), Shaft Capacity (P2), Helix Capacity (P3), and Soil Capacity (P4). The allowable capacity of a helical foundation system or device shall be the lowest value of P1, P2, P3, and P4, from each application illustrated in Figures 1 through 4. For evaluation of helical foundation devices subject to combined lateral loads and axial compression or axial tension, the allowable lateral capacity and allowable axial capacity shall be determined and reported separately. The allowable strength under combined load conditions shall be determined using the interaction equation provided in the AISC referenced standard.

3.2 P1 Bracket Capacity: The P1 bracket capacity is the maximum load that can be sustained by the bracket device of a helical foundation system based on strength in accordance with Section 3.10.

3.3 P2 Shaft Capacity: The P2 shaft capacity is the specified load that can be sustained by the shaft or coupling elements of a helical foundation device based on strength in accordance with Section 3.11.

3.4 P3 Helix Capacity: The P3 helix capacity is the specified load that can be sustained by the helix element of a helical foundation device based on strength or deformation in accordance with Section 3.12.

3.5 P4 Soil Capacity: The P4 soil capacity is the specified load that can be sustained by the soil or bedrock bearing stratum supporting the foundation system or device based on strength and settlement or pullout in accordance with Section 3.13.

3.6 Determination of Allowable Design Capacities: In accordance with Section 3.7 and Section 3.8, the allowable design capacities of helical foundation elements P1 and P2 shall be evaluated based on Conventional Design with no testing required, Special Analysis with verification tests, or solely on tests. All load tests shall be conducted in accordance with Section 4.0. The allowable capacity P3 shall be determined through load testing only as prescribed in Section 3.12. The allowable capacity P4 shall be determined by registered design professional or through installation torque correlations as specified in Section 3.13.

3.7 Design Methods:

3.7.1 Conventional Design: For conventional design of steel, either Allowable Stress Design (ASD) or Load and Resistance Factor Design (LRFD) methods referenced in the IBC or UBC may be used to calculate the allowable design capacity, P' . For design of concrete, strength design methods referenced in ACI 318 (IBC) or the UBC shall be used to calculate the design capacity.

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3.7.1.1 ASD Method: When using the ASD method, the allowable design capacity, P' , shall be taken as the allowable strength, P_a , and shall be determined in accordance with the applicable code or referenced standard (Eq-3).

$$P' = P_a \quad (\text{ASD}) \quad (\text{Eq-3})$$

3.7.1.2 LRFD Method: When using the LRFD method, the allowable design capacity, P' , shall be taken as 0.7 times the design strength, ϕP_n , ϕP_n determined in accordance with the applicable code or referenced standard (Eq-4).

$$P' = 0.7\phi P_n \quad (\text{LRFD}) \quad (\text{Eq-4})$$

3.7.2 Special Analysis: Where special analysis is used, the allowable capacity P' shall be taken as 0.6 times the resistance based on yield strength (P_y) or, when stress concentrations are prevalent, P' shall be 0.5 times the resistance based on maximum strength (P_{max}) (Eq-5).

$$P' = 0.6P_y \text{ or } 0.5P_{max} \quad (\text{Special Analysis}) \quad (\text{Eq-5})$$

3.7.3 Direct Measurement: Where load testing only is used and the number of samples is not specified, the allowable capacity shall be reported as the average allowable strength determined in accordance with Section 4.0 from tests conducted on at least five specimens, provided all test results are within 15 percent ($\pm 15\%$) of the average. Otherwise, the allowable capacity from testing only shall be based on the least test result. For direct measurement of helical foundation device capacities, testing shall be conducted in accordance with the applicable test procedure described in Section 4.0. The allowable capacity, P' , shall be taken as 0.6 times the resistance based on yield strength (P_y) or 0.5 times the maximum strength (P_{max}), whichever yields the lowest value (Eq-6).

$$P' = 0.6P_y \text{ or } 0.5P_{max} \quad (\text{Direct Measurement}) \quad (\text{Eq-6})$$

For direct measurement of soil capacity, testing shall be conducted in accordance with Section 4.4.1.2. For determination of allowable soil capacity, a factor of safety equal to 2 or greater shall be applied to the maximum measured soil capacity.

3.8 Capacity Limits: For conventional design, the maximum allowable design capacity of helical foundation systems and devices is 60 kips (266.9 kN) in axial tension and axial compression and 6 kips (26.7 kN) in lateral resistance. Helical foundation systems or devices with allowable design capacities greater than these normal capacity limits require special analysis with additional verification testing as prescribed in Sections 3.10 to 3.13.

3.9 Corrosion: Helical foundation systems and devices shall be bare steel, powder-coated steel or zinc-coated steel. Powder coatings shall comply with the ICC-ES Acceptance Criteria for Corrosion Protection of Steel Foundation Systems Using Polymer (EAA) Coatings (AC228) and the coating thickness shall be at least 450 μm (0.018 inch). Zinc coatings shall comply with ASTM A 123, A 153, B 633, or B 695, as applicable. Loss in steel thickness due to corrosion shall be accounted for in determining structural capacities by reducing the thickness of all helical foundation components by the sacrificial thickness over a period, t , of 50 years. The design thickness, T_d , of helical foundation components used in capacity calculations and testing shall be computed by Eq.-

6. For purposes of design calculations and fabrication of test specimens, the thickness of each component shall be reduced by $\frac{1}{2} T_s$ on each side, for a net reduction in thickness of T_s .

$$T_d = T_n - T_s \quad (\text{Eq-6})$$

where T_n is nominal thickness and T_s is sacrificial thickness ($t = 50$ yrs).

$$T_d \leq \text{base steel thickness}$$

$$\text{Zinc-coated steel: } T_s = 25 t^{0.65} = 318 \mu\text{m} (0.013 \text{ in})$$

$$\text{Bare steel, } T_s = 40 t^{0.80} = 915 \mu\text{m} (0.036 \text{ in})$$

Powder coated steel:

$$T_s = 40(t-16)^{0.80} = 671 \mu\text{m} (0.026 \text{ in})$$

For bare steel and powder-coated steel, T_n shall be the base-steel thickness. For zinc-coated steel, T_n may be the sum of the base-steel thickness and zinc coating thickness, provided the minimum zinc coating thickness is 86 μm (0.0034 in). Otherwise, the sacrificial thickness, T_s , shall be determined by linear interpolation between bare steel and zinc coated steel using the actual specified zinc coating thickness.

For powder-coated steel, the life of powder coating is taken as 16 years maximum. Hence, t has been reduced by 16 in the determination of T_s .

For verification of Special Analysis or for determination of allowable capacity through testing only, test specimens shall be constructed using steel thickness equal to T_d . Alternatively, unaltered test specimens may be used and the resulting allowable strength shall be reduced by multiplying the result by a scaling factor that takes into account corrosion and the observed failure mode. Thus, a tension failure result shall be scaled by the area of the fracture surface, while a flexural failure would be scaled by the reduced section modulus. The testing laboratory shall determine the appropriate scaling method and identify the failure mode.

Corrosion loss shall be accounted for regardless of whether devices are below or above ground or embedded in concrete. Zinc-coated steel and bare steel components shall not be combined in the same system. Powder coated steel may be combined with zinc-coated steel and bare steel components. All helical foundation components shall be galvanically isolated from concrete reinforcing steel, building structural steel, or any other metal building components.

3.10 P1 Bracket Capacity: Helical foundation brackets shall be classified as one of four types: side vertical load, direct load, slab support compressive load and tension anchor load. These types of brackets are illustrated in Figures 1 through 4. Bracket capacity shall be evaluated separately for each type. At a minimum, evaluation of P1 shall include determination of strength of the connection of the bracket to the structure, the internal strength of the bracket itself, and the strength of connection of the bracket to the helical foundation shaft. The frictional resistance of concrete on a horizontal bracket component shall be determined using a coefficient of friction of 0.4 or less. The shear strength of concrete also shall be calculated in accordance with the applicable code. Brackets may be evaluated for compression, tension, and/or lateral strengths, depending on the type. The angle of the shaft with respect to the bracket recommended by the installation instructions

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shall be accounted for in the calculations. The evaluation shall include an allowance for a tolerance of 1 degree from the permissible angle of inclination. Effects of helical foundation shaft inclination relative to vertical shall be accounted for in the analysis for axial compression or axial tension loads by incorporating a lateral component of forces in the analysis of the bracket, helical foundation shaft, and bracket connections. The shaft and the bracket shall be attached by a mechanical connection. Installation shall be limited to support of uncracked concrete, as determined in accordance with the applicable code. In order for the shaft to be considered side sway braced, the structure shall provide lateral restraint to the shaft equal to or greater than 0.4 percent of the shaft's allowable axial compression load.

3.10.1 Type A Side Load: Type A brackets are illustrated in Figure 1 and support tensile or compressive loads that are not concentric with the primary axis of the helical foundation shaft. Use of Type A brackets for supporting lateral loads is outside the scope of this criteria. Rotational moments caused by load eccentricity shall be subdivided into two components, bracket eccentricity and structure eccentricity, as illustrated in Figure 5. The shaft and the connected bracket components, consisting of the connected bracket, connection of the bracket to the shaft, and connection of the bracket to the structure, shall resist bracket eccentricity. Structure eccentricity varies with application and is generally resisted by the internal strength of the structure to which the bracket is attached. Therefore, resistance to structure eccentricity shall be determined on a case-by-case basis. For purposes of bracket eccentricity and internal strength design, the location of the resultant vertical compression force of the concrete structure on an angle bracket shall be taken as the centroid of an area defined by the uniform concrete bearing stress, taken as $0.35f_c$ for ASD and $0.55f_c$ for LRFD as shown in Figure 5. Type A brackets shall only be used to support structures that are braced as defined in IBC Section 1808.2.5. The strength of connected bracket components, shafts shall be evaluated based on one of two methods of proportioning moment between helical foundation shaft and connected bracket components. The first method is based on allowable stress design and is described in Section 3.10.1.1. The second method is based on limit state analysis and is described in Section 3.10.1.2.

3.10.1.1 Allowable Stress Design: This method of evaluation assumes the resistance to overturning moment is proportioned between the helical foundation shaft and the connected bracket components based on relative stiffness. The overturning moment caused by bracket eccentricity shall be proportioned between helical foundation shaft and connected bracket components using Eq-7a.

$$G = E_p I_p / E_b I_b \quad (\text{Eq-7a})$$

where:

I_p = Moment of inertia of helical foundation shaft (in⁴ or mm⁴).

E_p = Modulus of elasticity of helical foundation shaft (psi or MPa).

I_b = Moment of inertia of connected bracket components (in⁴ or mm⁴).

E_b = Modulus of elasticity of connected bracket components (psi or MPa).

If $G > 10$ Method a applies.

If $G < 0.1$ Method b applies.

If $0.1 \leq G \leq 10$ Method c applies.

The stiffness of the helical foundation shaft can be increased by reinforcing the top section of shaft with an outer sleeve, T-pipe, or other means. Based on the resulting value of G, the corresponding method in Sections 3.10.1.1.1 to 3.10.1.1.3 shall apply.

3.10.1.1.1 Method a: Rigid Shaft: This method of evaluation assumes the shaft and its connection to the bracket are relatively rigid compared to the connection of the bracket to the structure. By this method, the shaft shall resist the moment due to bracket eccentricity. A free body diagram of the bracket based on this method is illustrated in Figure 5(a). The free body diagram is statically determinate. Separate evaluation of helical foundation bracket devices by this method shall include evaluation of P2 for all specified helical foundation shafts to be used with the bracket. In the analysis of the shaft, a moment shall be applied to the top of the shaft equal to the eccentricity of the bracket times the axial load.

3.10.1.1.2 Method b: Flexible Shaft: This method of evaluation assumes the helical foundation shaft and/or its connection to the bracket are relatively flexible compared to the connection of the bracket to structure. By this method, the connection of the bracket to the structure is required to resist the moment due to bracket eccentricity. Axial loads are transmitted concentrically to the helical foundation shaft. A free body diagram of the bracket based on this method is illustrated in Figure 5(b). The free body diagram is statically determinate.

3.10.1.1.3 Method c: Combined Stiffness: This method of evaluation assumes the shaft and the connection of the bracket to the structure are of similar stiffness. In this case, both the shaft and structure contribute to resisting the moment due to bracket eccentricity. A free body diagram of the bracket based on this method is illustrated in Figure 5(c). The free body diagram is statically indeterminate. Numerical analysis, finite element modeling, strain compatibility, or other Special Analysis shall be used to determine allowable capacity. Alternatively, the moment exerted on the shaft and the connection of the bracket to the structure can be proportioned using G, and the capacity of the bracket can be statically determined using Conventional Design described in Section 3.7. Evaluation of P1 bracket capacity by this method shall include a specified shaft and is necessarily coupled with evaluation of P2 shaft capacity. In the analysis of the shaft, a moment shall be applied to the top of the shaft equal to the eccentricity of the bracket times the appropriate proportion ($G/(G+1)$) of axial load.

3.10.1.2 Limit State Design: This method of evaluation assumes at failure that the connection between the bracket and structure reaches a maximum limit state and the helical foundation shaft has a plastic hinge. Based on these assumptions, the rotational stability of a side load bracket is statically determinate. The nominal load capacity of the bracket shall be determined by simultaneous solution of static equilibrium equations. In the static analysis, the moment at the connection of the helical foundation shaft to the bracket or T-pipe shall be set equal to the moment resistance of the shaft based on combined axial and flexural loading. The shear at the connection of the helical

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foundation shaft to the bracket or T-pipe shall be determined by Eq-7b.

$$V_p = M_p/d \quad (\text{Eq-7b})$$

where

M_p = Moment resistance of helical foundation shaft from combined axial and flexural load analysis (in-lbf or N-mm).

V_p = Shear in helical foundation shaft at the connection to the bracket or T-pipe (lbf or N).

d = 60 inches (1524 mm).

3.10.1.3 Connection to the Structure: Axial compression, axial tension, or lateral load connection capacities shall be determined in accordance with the IBC, UBC, or a current ICC-ES evaluation report. For purposes of evaluation, the structure shall be modeled as a mass of structural plain concrete, semi-infinite in extent, with varying strength. The structure shall be assumed to be fixed in translation and rotation, but can move freely in the vertical direction. At a minimum, design of the connection shall be based on normal-weight concrete with a specified compressive strength of 2,500 psi (17.22 MPa). Other concrete strengths, structural lightweight concrete, masonry and other materials also can be included in the evaluation at the option of the bracket manufacturer. For all combinations of concrete strength and/or material compositions, details regarding connection of the bracket to the structure types (i.e., anchor bolt placement, grouting, surface preparation, etc.) shall be prescriptively specified.

3.10.2 Type B: Direct Load: Type B brackets illustrated in Figure 2, support axial compressive or axial tension loads that are concentric with the primary axis of the helical foundation shaft and may be used to support lateral loads. The strength of bracket components and connections shall be evaluated in accordance with Section 3.10.2.1 or Section 3.10.2.2 depending on whether the structure to be supported by the bracket is side sway braced.

3.10.2.1 Method 1: Sidesway Braced: This method of evaluation assumes the connection of the bracket to the structure provides lateral but not rotational bracing for the top of the helical foundation shaft so that the top of the shaft is essentially a pinned connection.

3.10.2.2 Method 2: Sidesway Unbraced: This method of evaluation assumes the structure provides neither lateral nor rotational bracing for the top of the helical foundation shaft, so that the top of the shaft is essentially a free connection.

3.10.2.3 Connection to the Structure: The structures that Type B brackets are used to support may be concrete, steel, wood or other material. Evaluation shall include specifications for connection to structures, such as material strength, embedment depth, edge distance, welds, bolts, bearing area, and bracing. Connection of the bracket to each type of structure (grade beams, walls, steel beams, posts, etc.) for which evaluation is being sought shall be detailed and analyzed separately. At a minimum, design of the connection shall be based on normal-weight concrete with a specified compressive strength of 2,500 psi (17.22 MPa). The analysis shall include considerations of internal shear and moment within concrete elements, as applicable. Analysis of wood, steel, and concrete shall be based on the

IBC, UBC, AISC LRFD, AISC ASD, AF&PA, NDS, or ACI 318, as applicable.

3.10.3 Type C: Slab Support: Type C brackets support concrete flatwork. These brackets shall support axial compression loads concentrically. Use of Type C brackets for supporting tension or lateral loads is outside the scope of this criteria. Calculations shall be performed proving whether the bracket can be considered sidesway braced. Evaluation shall comply with Section 3.10.2.1 of the criteria for Type B direct load brackets, Method 1, and shall include analysis of punching shear based on ACI 318 in concrete slabs of different strength and different thickness slabs, along with recommended bracket spacing for slabs supporting 40 psf (1915 Pa) to 100 psf (4788 Pa) uniform live loads. At a minimum, evaluation shall include 4-, 6-, and 8-inch-thick (102, 152, and 203 mm), unreinforced slabs containing normal-weight concrete with minimum specified compressive strength of 2,500 psi (17.22 MPa). Other concrete strengths and structural lightweight concrete also can be included in the evaluation at the option of the bracket manufacturer.

3.10.4 Type D: Tension Anchor: Type D brackets are used to support axial tension loads only. These brackets shall support loads concentrically and shall not be evaluated for lateral load resistance. Evaluation shall comply with Section 3.10.2 of the criteria for Type B direct load brackets. The connection to the existing structure shall be evaluated, including the range of acceptable shaft installation angles proposed by the manufacturer.

3.10.5 Test Requirements: Verification tests shall not be required for evaluation of foundation brackets provided all analysis is accomplished using Conventional Design as set forth in Section 3.7 and allowable capacities are within the range of Normal Capacity Limits as set forth in Section 3.8. A minimum of three verification load tests shall be conducted in each load direction (axial compression, axial tension, and lateral) on any component of a bracket or bracket/shaft system evaluated using Special Analysis and for brackets exceeding Normal Capacity Limits. Where tests are required for verification of lateral resistance, tests shall be conducted to verify lateral resistance in all directions for which lateral resistance is being claimed. Bracket tests shall be conducted in accordance with Section 4.1 for compression and tension and Section 4.4.2 for lateral resistance.

3.11 P2 Shaft Capacity: At a minimum, helical foundation shaft capacities shall be evaluated for torsion and either axial compression, axial tension, or both. Shafts may also be evaluated for lateral resistance with consideration of combined lateral and axial loading. Evaluation of shafts shall include connections between shafts. All shaft connections shall be made via a mechanical coupling.

3.11.1 Tension: Shaft evaluation for tension shall include yielding on the gross area and fracture at any couplings. At couplings, there shall be consideration of fracture on the net area of the main member, fracture on the net area of the sleeve, bearing of fasteners such as pins or bolts on the net areas of fastener holes, shearing of the fasteners, block shearing of the main member and sleeve, and the attachment of the sleeve to the main member.

3.11.2 Compression: Shaft evaluation for compression shall include buckling resistance, yielding on the gross area,

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and yielding at any couplings. At couplings, there shall be consideration of bearing of the fasteners such as pins or bolts on the net area of the fastener holes, shearing of the fasteners, and the attachment of the sleeve to the main member. A bending moment shall be applied to the top of the shaft in buckling calculations in accordance with Section 3.10 and Section 3.11.2.3.

3.11.2.1 Unsupported Length: Unsupported shaft lengths shall include the length of the shaft in air, water, or in fluid soils. For unbraced systems, the lengths specified in IBC Section 1808.2.9.2 shall apply unless determined otherwise by Special Analysis. In accordance with IBC Section 1808.2.9.1, any soil other than fluid soil shall be deemed to afford sufficient lateral support to prevent buckling of systems that are braced. Bracing shall comply with IBC Section 1808.2.5. Firm soils shall be defined as any soil with a Standard Penetration Test blow count of five or greater. Soft soils shall be defined as any soil with a Standard Penetration Test blow count greater than zero and less than five. Fluid soils shall be defined as any soil with a Standard Penetration Test blow count of zero [weight of hammer (WOH) or weight of rods (WOR)]. Standard Penetration Test blow count shall be determined in accordance with ASTM D 1586.

3.11.2.2 Effective Length: Effective lengths shall be determined using the unsupported length defined in Section 3.11.2.1 and the appropriate effective length factor, K , determined in accordance with the AISC referenced standard. Slenderness ratio limitations as specified by the AISC referenced standards do not apply.

3.11.2.3 Coupling Rigidity: Coupling rigidity shall be considered for all cases except braced systems in firm or soft soils. To account for coupling rigidity, the eccentricity of the axial compressive load applied to the shaft shall be increased by a distance, ne_c , where n is the number of couplings possible in the unsupported length and e_c is the maximum lateral deflection of the unsupported length of shaft due to flexure of the coupling under an applied lateral load of 0.4 percent of the applied axial compressive load. Maximum lateral deflection of the shaft due to coupling flexure shall be determined in accordance with Section 4.2.4.

3.11.3 Torsion: Torsion resistance shall be determined by testing in accordance with Section 4.2.2. A minimum of 12 samples, with an equal number of samples from four or more separate heats, shall be used for the basis of testing. The mean ultimate (maximum) torsion resistance and standard deviation shall be determined from the test population. Based on test results, maximum installation torque shall be reported as two standard deviations below the mean ultimate (maximum) torque from the sample population. Torsional strength need not be evaluated for corrosion losses.

3.11.4 Lateral Resistance: Lateral resistance of the shaft is necessarily coupled with soil capacity and shall be determined in accordance with Section 3.13. Shaft area, moment of inertia, and elasticity shall be used as inputs in the analysis. Maximum bending moment and shear stress determined from the analysis shall be limited by the allowable bending and shear resistance of the shaft or the shaft couplings, whichever is less. Deflection of shaft couplings shall be included in lateral resistance analysis.

3.11.5 Elastic Shortening or Lengthening: Methods (equations) shall be provided for estimation of elastic shortening/lengthening of the shaft under the allowable axial load plus any slip in the couplings. These methods shall be based upon Conventional Design.

3.11.6 Combined Stresses: Shaft evaluation shall include combined stresses. Combinations of tension, compression, bending, and lateral loads shall be considered as applicable.

3.11.7 Test Requirements: Verification tests shall not be required for evaluation of shaft tension, compression, and bending moment provided all analysis is accomplished using Conventional Design in accordance with Section 3.1 and allowable capacities are within the range of Normal Capacity Limits as set forth in Section 3.8. A minimum of three verification load tests shall be conducted on separate specimens in each direction (compression, tension, bending) on any component of a shaft evaluated using Special Analysis and for shafts that exceed Normal Capacity limits as set forth in Section 3.8. Tests are required to determine torsion resistance of all shafts and coupling rigidity as described in Sections 3.11.2.3 or 3.11.3. Tests for shaft capacity shall be conducted in accordance with Section 4.2.

3.12 P3 Helix Capacity: Helix capacities shall be evaluated for torsional resistance, punching flexure, weld flexure, and weld shear in tension and compression. Evaluation shall be based solely on testing. The allowable helix capacity, P3, for helical foundation systems and devices with multiple helices shall be taken as the sum of the least design allowable capacity of each individual helix. The allowable capacity of the helix in torsion shall be considered acceptable provided it exceeds the torsional strength of the shaft.

3.12.1 Lateral Capacity: The determination of the lateral capacity of the helix is not permitted. The lateral capacity of a helical foundation system is based on the resistance of the shaft only and is not significantly affected by the presence of helix bearing plates.

3.12.2 Torsion: Torsion resistance of helix bearing plates can be determined in conjunction with shaft torsion or independently. In either case, testing shall be conducted in accordance with Section 4.2.2 using the number of samples and the same procedures described in Section 3.11.3.

3.12.3 Test Requirements: Each diameter, thickness, steel grade, pitch, and edge geometry helix, for which evaluation is being sought, shall be tested. The allowable capacity for each size and type of helix shall be reported as the average result of at least three test specimens. In order to allow the mean values, individual results determined from testing shall be within 15 percent of the average of tests. Otherwise, the least test result shall apply. At least one laboratory test shall be conducted to verify the torsional shear strength of each helix for installation purposes. Helix punching, weld flexure, and weld shear tests shall be conducted in accordance with Section 4.3. Helix torsion resistance shall be tested in accordance with Section 4.2.2.

3.13 P4 Soil Capacity: Soil capacity includes the tension, compression, and/or lateral resistance of a helical foundation embedded in ground, as applicable.

3.13.1 Axial Capacity Verification: For all helical foundation systems, full-scale field installation and load tests

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shall be conducted to verify the axial capacity on specimens installed to the maximum installation torque determined in accordance with Section 3.11.3. The tests shall be regarded as a successful verification of installation and allowable capacity, provided the maximum allowable torque is achieved during installation without significant damage to the helical foundation shaft and all full-scale axial load tests exceed the allowable capacity of the system by a factor of safety of at least 2.0.

At least two specimens of each type of helical foundation shaft shall be tested in each load direction (tension or compression) for which evaluation is being sought. Variations in shaft size and material strengths, as well as helix pitch, helix thickness, and edge geometry, shall constitute a different type of specimen. Two separate specimens shall be tested in each direction (compression and/or tension) for which evaluation is being sought. Test specimens shall consist of a shaft, at least one shaft coupling, and a single helix. The helix size shall include the smallest available helix diameter for one test and the largest available helix diameter for the other test. The test specimen may include a bracket. All verification tests shall be conducted at sites described in Section 3.13.4. Additional information on testing is provided in Section 3.13.5. The determination of soil capacity, P_4 , on any specific site or with any configuration of helical bearing plates other than the test site and test specimen is outside the scope of this acceptance criteria. The evaluation report shall indicate that soil capacity shall be determined by a registered design professional for each site considering groundwater and other geotechnical conditions. As an alternative, torque correlations for specific soil conditions may be determined in accordance with Section 3.13.2.

3.13.2 Torque Correlations: Evaluation reports may include a correlation between final installation torque, T , and ultimate (maximum) axial capacity, Q , given by Eq-8:

$$Q = K_t T \quad (\text{Eq-8})$$

where K_t is the axial tensile or compressive load capacity to torque ratio for a given helical foundation type. The allowable capacity, Q_a , shall be computed by Eq-9:

$$Q_a = 0.5Q \quad (\text{Eq-9})$$

If included in the evaluation report, the parameter K_t shall be verified by full-scale field installation and load tests. The number of tests required depends on whether the helical foundation system is conforming or nonconforming. Separate torque correlations are required for shafts with differing geometry and outside dimensions and for each helix plate style (pitch, thickness, geometry). Field tests may be conducted at any site provided a geotechnical engineering report is obtained for the site in accordance with Section 3.13.4 and the soil profile generally matches that shown in Table 2.

3.13.2.1 Conforming Systems: Systems shall be considered conforming based on compliance with the criteria given in Table 3. The following capacity to torque ratios (K_t) shall be reported for conforming products.

1.5-inch- and 1.75-inch-square shafts	$K_t = 10 \text{ ft}^{-1}$
2.875-inch outside diameter round shafts	$K_t = 9 \text{ ft}^{-1}$
3.0-inch outside diameter round shafts	$K_t = 8 \text{ ft}^{-1}$
3.5-inch outside diameter round shafts	$K_t = 7 \text{ ft}^{-1}$

The number of tests required to verify capacity to torque ratios for conforming products shall be as shown in Table 2. The correlation between torque and capacity shall be deemed verified if all of the ultimate (maximum) soil capacities determined from load tests conducted in accordance with Section 3.13.2 exceed the allowable capacity determined using the forgoing K_t values and provided the average ratio of ultimate (maximum) soil capacity determined in field tests to predicted allowable capacity determined using K_t is equal to or greater than two (2.0). If verification is not obtained, these helical foundation systems and devices shall be deemed as non-conforming and shall be subject to the additional testing as set forth in Section 3.13.2.2.

3.13.2.2 Nonconforming Systems: Systems that fail to comply with the criteria in Table 3 or that fail verification tests given in Section 3.13.2.1 shall be deemed nonconforming. Conforming systems also may be deemed non-conforming if values of K_t higher than provided in Section 3.13.2.1 are desired. In order to establish K_t values for these systems, at least eight additional field tests shall be conducted in compression and six additional tests shall be conducted in tension in addition to the quantity shown in Table 2. These tests shall involve a range of at least three different helix combinations and at least three different soil types. The subsurface profile at each test site shall be determined in accordance with Section 3.13.4.

Test sample population shall be plotted versus the ratio Q_t/Q , where Q_t is ultimate (maximum) soil capacity determined through full-scale field tests and Q is ultimate (maximum) soil capacity determined by correlations with torque using a constant K_t . An iterative approach shall be used to determine the value of K_t such that the mean value of Q_t/Q is equal to 1.0. The K_t value shall be considered valid if 94 percent of the data have a Q_t/Q ratio greater than 0.5. Otherwise, a correlation between capacity and torque is invalid for that product and cannot be reported.

3.13.3 Lateral Resistance: Allowable soil capacity in the lateral direction shall be determined through load tests on specimens installed in different soil conditions. The allowable soil capacity shall be determined based on deflection criteria set forth in Section 4.4.2. In order to be valid, allowable capacities determined for each type of specimen in each soil type shall be within 15 percent of the average allowable capacity for those tests.

A minimum of four specimens of each type of helical foundation shaft shall be tested in each soil type for which evaluation is being sought. Variations in shaft size, shaft geometry, and material strength shall constitute a different type of specimen. Variations in helix size, geometry, pitch, material strength, thickness, and number do not require separate tests. Four separate specimens shall be tested in each transverse direction for which evaluation is being sought if the shaft is not axially symmetric. Test specimens shall consist of a shaft, at least one shaft coupling located within the manufacturer's smallest extension length from the ground surface, and one or more helix bearing plates. The test may include a bracket.

At a minimum, evaluation shall include tests in firm clay soils. Additional tests may be conducted in different soil conditions from other sites. The subsurface profile at all test sites shall be characterized in a soil investigation by a registered design professional. Additional information on

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testing is provided in Section 3.13.4. Allowable soil capacity for different specimens in different soil categories shall be tabulated in the evaluation report. The evaluation report shall contain a statement that soil capacity for lateral resistance in soils conditions that substantially differ from actual test sites included in the evaluation shall be determined by a registered professional engineer on a case-by-case basis.

3.13.4 Test Requirements: Axial compressive, tensile, and lateral allowable load capacity shall be verified through field load tests as provided in Section 3.13.3. At least two verification tests are required for axial compression and at least two verification tests are required for axial tension. If a ratio between final installation torque and capacity is specified, then at least eight tests are required for axial compression verification and at least six tests are required for axial tension verification for each shaft size for which evaluation is being sought. The two verification tests required for compression and tension may be included in the tests for torque correlations. No additional tests are required for establishing torque correlations for conforming products, whereas nonconforming products will require eight additional tests in compression and six additional tests in tension for each shaft size. If evaluation of lateral resistance is requested, four verification tests are required for each shaft size, shaft geometry, and soil type.

Tests for axial compression and tension soil capacity shall be conducted in accordance with Section 4.4.1 and tests for lateral resistance shall be conducted in accordance with Section 4.4.2. Tension and compression verification load tests are required to be conducted at the facility or field station of a testing laboratory complying with Section 2.2. The subsurface profile at other test sites shall be characterized in a soil report by a registered design professional. Subsurface profile characterization shall include soil borings, standard penetration resistance tests, and basic laboratory classification tests essential for soil classification according to the Unified Soil Classification System. All field penetration tests, laboratory tests, and soil classifications shall be conducted in accordance with ASTM D 1586.

4.0 TEST METHODS

4.1 P1 Bracket Capacity: Where specified herein, each size and configuration of the bracket shall be tested. The configuration of the bracket and direction of applied loads in the test apparatus shall be as close to actual field conditions as practical. Pertinent data such as maximum load applied, maximum bracket rotation, failure mode, etc. shall be reported.

4.1.1 Type A Side Load:

4.1.1.1 Setup: Compression and tension tests can be conducted in a horizontal configuration, as illustrated in Figure 6. The bracket shall be mounted to a block of plain concrete of known strength that is fixed with respect to translation and rotation. The connection of the bracket to the concrete shall be in accordance with manufacturer's installation instructions. Load shall be applied to the bracket using a 60 inch (1524 mm) long section of helical foundation shaft secured to the bracket in a manner that duplicates actual field conditions. The loaded end of the shaft shall be rotationally fixed. Axial load shall be applied in the direction of the longitudinal axis of the helical foundation shaft. Any eccentricity inherent in the bracket configuration and

manufacturer-recommended angle of the shaft to bracket shall be accounted for and shall be modeled to match the anticipated design purpose.

4.1.1.2 Procedure: Axial deflection shall be recorded as a function of applied load at regular intervals equal to or less than 20 percent of the anticipated allowable load. The rate of load application shall be sufficiently slow to simulate static conditions. Each load increment shall be held for a minimum of 1 minute. Yield strength and ultimate (maximum) strength of the bracket shall be determined using conventional analysis of a plot of load versus deflection. The allowable strength of the bracket shall be determined from yield or ultimate (maximum) strength using the equations provided in Section 3.7.3, whichever formula results in the lowest value. Compression tests shall be conducted within 24 hours of the bracket test on concrete cylinders cast at the same time as the test specimen to establish concrete compressive strength. Cylinders shall be stored and cured according to Section 9.3.1 of ASTM C 31 (field cure). The tested concrete compressive strength shall be within 15 percent of the specified compressive strength. Concrete cylinder compression tests shall be conducted in accordance with ASTM C 39.

4.1.2 Type B: Direct Load:

4.1.2.1 Setup: The test bracket shall be mounted to a fixture that is substantially similar to the structure for which the bracket is intended to support. The fixture representing the structure shall be translationally and rotationally fixed as appropriate to simulate field conditions, as illustrated in Figure 7. The connection of the bracket to the fixture shall be in accordance with manufacturer's installation instructions. The load shall be applied to the bracket using a 60-inch-long (1524 mm) section of helical foundation shaft secured to the bracket in a manner that duplicates actual field conditions. The loaded end of the shaft shall be rotationally fixed. Axial load shall be applied in the direction of the longitudinal axis of the helical foundation shaft. Any inclination of the shaft with respect to the structure shall be modeled to match the anticipated design purpose. For tests of the lateral capacity of a bracket and the connection of the bracket to a structure, the load test shall be set-up as described herein, except that the load shall be applied normal to the shaft at a location as close to the base of the cap as possible. In order to avoid application of flexure to the shaft during loading, a roller guide shall be used to facilitate load application as shown in Figure 7.

4.1.2.2 Procedure: Depending on the purpose of the test, axial or lateral deflection shall be recorded as a function of applied load at regular intervals equal to or less than 20 percent of the anticipated allowable load. The rate of load application shall be sufficiently slow to simulate static conditions. Each load increment shall be held for a minimum of 1 minute. Yield strength and ultimate (maximum) strengths of the bracket shall be determined using conventional analysis of a plot of load versus deflection. The allowable strength of the bracket shall be determined from yield or ultimate (maximum) strength and the equations provided in Section 3.7.3, whichever formula results in a lower value. If a concrete structure is used in the load test, the strength of the concrete shall be tested in accordance with the procedures in Section 4.1.1.2.

4.1.3 Type C: Slab Support:

4.1.3.1 Setup: Compression tests shall be conducted by casting a concrete slab with specified thickness and

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dimensions equal to the manufacturer's recommended helical foundation shaft spacing for that thickness slab and anticipated loading. The slab support bracket and a section of helical foundation shaft shall be mounted in an inverted fashion over the slab, as illustrated in Figure 8. A hole consistent with manufacturer's recommendations shall be cored through the slab in the bracket location and subsequently filled with cementitious grout. The slab shall be supported on a flexible air diaphragm sufficient to withstand the imposed loads. The length of the helical shaft used in the test shall be at least six times the diameter of the shaft. As an alternative, the slab, bracket, shaft, and air diaphragm may be mounted in a horizontal load frame.

4.1.3.2 Procedure: Downward compression loads shall be applied axially to the end of the shaft. Axial deflections shall be recorded as a function of applied load at regular intervals not exceeding 20 percent of the anticipated allowable load. The rate of load application shall be sufficiently slow to simulate static conditions. Each load increment shall be held for a minimum of 1 minute. Yield strength and ultimate (maximum) strengths of the bracket shall be determined using conventional analysis of a plot of load versus deflection and may depend heavily on slab shear. The allowable strengths of the bracket shall be determined from yield or ultimate (maximum) strength and the equations provided in Section 3.7.3, whichever formula results in the lowest value. The compressive strength of the concrete shall be verified in accordance with the procedures described in Section 4.1.1.2.

4.1.4 Type D: Tension Anchor:

4.1.4.1 Setup: Load tests shall be conducted on Type D anchor brackets by attaching the bracket to a short section of helical foundation shaft following the evaluation report applicant's recommendations. The bracket shall be cast into a concrete test specimen or otherwise attached to a structure that substantially conforms to the manufacturer's recommended connection details including minimum washer plate size, concrete cover, and concrete reinforcement as applicable. The specimen shall be placed in tension in a laboratory load frame, as illustrated in Figure 9. Deflection of the anchor bracket shall be measured with a dial gauge. The load shall be determined with a calibrated load cell. The length of the shaft used in the test shall be at least six times the shaft diameter.

4.1.4.2 Procedure: The specimen shall be loaded in increments not exceeding 20 percent of the calculated allowable capacity. The rate of load application shall be sufficiently slow to simulate static conditions. Each load increment shall be held for a minimum of 1 minute. Deflections and loads at the completion of the hold period for each increment shall be measured. The specimens shall be loaded until plastic yielding or brittle fracture occurs. The failure mode shall be reported. A plot of deflection versus load shall be reported. The allowable strength of the bracket shall be determined from yield or ultimate (maximum) strength and the equations provided in Section 3.7.3, whichever equation results in a lower value, along with the corresponding deflection as determined from the load-deflection plot. If applicable, the strength of the concrete shall be verified in accordance with the procedures described in Section 4.1.1.2.

4.2 P2 Shaft Capacity:

4.2.1 Axial Tension and Compression:

4.2.1.1 Setup: Tension and compression tests shall be conducted on a section of shaft with a coupling located approximately at the midpoint of the shaft specimen. The test specimen shall be mounted to a vertical or horizontal load frame with one end attached to a fixed platform and the other end attached to a mobile platform with the capability to apply the load to the specimen in the axial direction. The coupling connection shall be done in accordance with manufacturer's specific published recommendations. Direction of loading shall be coaxial with the longitudinal axis of the shaft. The testing apparatus shall provide sufficient rigidity as to minimize any slip or deformation not associated with the test specimen. The shaft shall have sufficient length (each side of coupling) to allow a uniform tensile or compressive force to develop in the shaft prior to reaching the connection. To evaluate buckling resistance, compression specimens shall have a minimum length equal to or greater than the effective length as specified in Section 3.11.2.2.

4.2.1.2 Procedure: Loads shall be applied to the specimen in increments not exceeding 20 percent of the design allowable load of the specimen. Each load increment shall be held for a minimum of one minute. The specimen shall be loaded to failure. Application of the load shall be performed at a slow rate to simulate a statically applied load. Pertinent data such as maximum load applied, maximum shaft or connection deformation, failure mode, etc. shall be reported. Yield strength and ultimate (maximum) strength of the shaft and coupling shall be determined using conventional analysis of a plot of load versus deflection. The allowable strength of the shaft and coupling shall be determined from yield or ultimate (maximum) strength and the equations provided in Section 3.7.3, whichever equation results in a lower value.

4.2.2 Torsion:

4.2.2.1 Setup: Torsion testing shall be performed on a section of shaft with a minimum length of 36 inches (914 mm) or 12 times the maximum outside cross sectional dimension of the shaft; whichever is greater. The shaft shall have a standard manufactured coupling located approximately midway between the ends of the shaft specimen and a helix affixed to the end of the shaft. The specimen shall be fixed at the helix end and attached to a torque motor on the other end. The helix shall be fixed about the outside edge using six bolt clamps. The tests shall be conducted in a load frame that allows for measurement of the angle of twist, as illustrated in Figure 10. Torque shall be applied to a short section of shaft attached to the helix. The test setup shall include a means of measuring shaft coupling bolt hole elongation during the test. Alternatively, the helix may be tested separately at the evaluation report applicant's option. In the shaft torsion test without a helix, the specimen shall be fixed at one end of the shaft and attached to the torque motor on the other end. In the helix torsion test, the specimen shall consist of a short section of shaft attached to a helix plate. The helix shall be fixed about the outside edge as previously described herein and torsion shall be applied to the end of the shaft.

4.2.2.2 Procedure: As applicable depending on the test specimen configuration, the maximum torsion resistance shall be defined as that required to achieve 0.5 shaft revolution per foot (1.6 revolutions per meter) of shaft length, that which causes failure of the helix, coupling, or shaft, that which damages the coupling to an extent that it

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cannot be decoupled effectively, or that which elongates the coupling bolt hole 0.25 inch (6.4 mm), whichever occurs first. The rotation rate shall not exceed 20 rpm.

4.2.3 Bending:

4.2.3.1 Setup: Bending tests shall be conducted on a section of shaft that is horizontally arranged in a compression load frame, as illustrated in Figure 11. For shafts with a non-circular cross section, as a minimum, the tests shall be conducted with the least resistant orientation. The distance between shaft supports shall be at least 36 inches (914 mm) or 12 times the maximum outside cross-sectional dimension of the shaft, whichever is greater. A coupling shall be located approximately in the center of the specimen. Loads shall be applied using a two point test where the load points straddle the coupling so that a uniform bending moment is produced in the coupling.

4.2.3.2 Procedures: Load shall be applied and deflections measured at intervals of less than or equal to 20 percent of the load corresponding to the theoretical allowable bending moment. Application of load shall be performed at a slow rate to simulate a statically applied load. Pertinent data such as maximum load applied, maximum shaft or coupling deformation, failure mode, etc. shall be reported. Yield strength and ultimate (maximum) strength of the shaft and coupling shall be determined using conventional analysis of a plot of load versus deflection. The allowable bending strength of the shaft and coupling shall be determined from yield or (maximum) strength and the equations provided in Section 3.7.3, whichever equation results in a lower value.

4.2.4 Coupling Rigidity:

4.2.4.1 Setup: The maximum lateral deflection of shafts due to coupling flexure shall be determined using a section of shaft with length equal to the Unsupported Length [60 or 120 inches (1524 or 3048 mm) as specified by Section 1808.2.9.2 of the IBC]. The shaft shall have the maximum number of couplings possible over its length based on the available shaft sections. The shaft shall be horizontally or vertically arranged in a load frame at the evaluation report applicant's option with one end fixed and the other end unsupported, as illustrated in Figure 12. A load shall be applied perpendicularly to the unsupported end of the shaft.

4.2.4.2 Procedures: A vertical load equal to 0.4 percent of the allowable compression load on the helical foundation shaft system shall be applied. The total deflection of the loaded end of the shaft, including any free deflection, shall be measured relative to a horizontal plane extending from the fixed end. The total deflection shall be reported and used in shaft eccentricity computations.

4.2.5 Shear Strength:

4.2.5.1 Setup: The maximum shear strength of shafts and couplings shall be determined using specimens with lengths as appropriate for the test apparatus. The specimen shall be horizontally or vertically arranged in a load frame with one end fixed and the other end free. A load shall be applied normal to the shaft or coupling using a roller or slide to avoid inducing flexure into the system.

4.2.5.2 Procedure: The loads shall be applied in increments not exceeding 20 percent of the allowable shear load on the shaft or coupling. The total deflection of the shaft

or coupling at the point of load application shall be measured at each increment. Load shall be applied at a slow rate to simulate statically applied load. Each load increment shall be held for a minimum of one minute. Yield and ultimate (maximum) strength of the shaft or coupling shall be determined using a conventional analysis of a plot of load versus deflection.

4.3 P3 Helix Capacity:

4.3.1.1 Setup: Helix capacity tests shall be performed by placing a short section of shaft with a helix in a laboratory load frame, as illustrated in Figure 13. The helix plate shall bear on an adjustable mandrill with five or more pins or a helix-shaped fixture. The line of bearing shall be located at a distance from the central axis of the shaft equal to one-half the outer radius of the helix, R_b , plus the radius of the shaft, R_s . For non-circular shafts, R_s shall be the radius of a circle circumscribed about the outer extent of the shaft's cross-section. Direction of loading shall be coaxial with the longitudinal axis of the shaft and normal to the bearing plane of the helix.

4.3.1.2 Procedures: Load shall be applied and deflection recorded at intervals equal to 20 percent of the theoretical punching strength of the helix. Application of load shall be done at a slow enough rate as to simulate a statically applied load. Pertinent data such as maximum load applied, maximum helix deformation, failure mode, etc., shall be reported. Load shall be plotted as a function of deflection. Maximum strength of the helix shall be the peak load sustained by the helix. The allowable strength of the helix shall be determined from the maximum strength in accordance with Section 3.7.3.

4.4 P4 Soil Capacity:

4.4.1 Full-scale Load Tests:

4.4.1.1 Setup: Full-scale load tests shall be conducted in accordance with ASTM D 1143 for axial compression and ASTM D 3689 for axial tension. The quick load test procedure set forth in Section 5.6 of ASTM D 1143 shall be used in compression tests. Installation of the helical piers shall be done in accordance with the installation instructions. The brand, model number, and maximum torque capacity of the installation device shall be reported. All test piers shall be installed as close to vertical as possible. Pertinent data such as helical foundation shaft depth and final installation torque achieved shall be reported. Torque should be measured with a calibrated in-line indicator, or calibrated hydraulic torque motor via differential pressure. Calibration of torque motors and/or torque indicators shall be performed on equipment whose calibration is traceable back to NIST (National Institute of Standards and Technology). For tension tests, the helical foundation shaft shall be installed such that the minimum depth from the ground surface to the uppermost helix is $12D$, where D is the diameter of the largest helix.

4.4.1.2 Procedures: Direction of loading shall be coaxial with the longitudinal axis of the pier. Application of load shall be done at a slow rate to simulate a statically applied load. Piers shall be installed to the depth interval recommended for the designated helical foundation shaft test sites. Maximum load capacity shall be that which is achieved when plunging of the helix plate occurs or when net deflection exceeds 10 percent of the helix plate diameter, whichever occurs first. Net deflection shall be total

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deflection minus shaft elastic shortening or lengthening. For multiple helix configurations, the average helix diameter shall be used in this criterion.

4.4.2 Lateral Load Tests:

4.4.2.1 Setup: Lateral load tests shall be conducted in accordance with ASTM D 3966. These tests can be performed in two ways. If verification of lateral resistance of brackets is required, the test setup shall consist of a helical foundation representative of a standard installation with a bracket above the ground surface. The bracket shall be connected to a structure constructed from wood, steel, or concrete depending on the particular detail for which evaluation is being sought. The test setup shall be such that lateral load is applied to the structure being supported immediately above the bracket elevation. The tests shall be conducted with a free head arrangement in accordance with ASTM D 3966. Where the bracket is intended to support a structure that is rotationally restrained, the test may be conducted using fixed head or free head arrangements in accordance with ASTM D 3966.

If verification of bracket capacity is not required, as in the case of Conventional Design, then the tests shall be conducted with the helical foundation shaft extending a minimum of 12 inches (304.8 mm) from the ground surface. The lateral load shall be applied to the helical foundation shaft immediately above the ground surface. Depending on whether the helical foundation shaft is intended to support a structure that is rotationally restrained, the test may be conducted using fixed head or free head arrangements in accordance with ASTM D 3966.

Bracket and helical foundation installation shall be done in accordance with the standards set forth in manufacturer's specific published recommendations. All test piers shall be installed within the manufacturer's specified tolerances for angle of installation for the bracket type. Where brackets are not used, the shaft shall be installed within the manufacturer's specified tolerances for plumbness. The minimum depth of the uppermost helix shall be 180 inches (4572 mm) unless the helical foundation system is only available in a shorter length.

4.4.2.2 Procedures: For tests including brackets or shafts that are non symmetrical, separate specimens shall be loaded in all lateral directions for which evaluation is being sought. Application of load shall be done at a slow rate to simulate a statically applied load. The allowable load capacity reported shall be equal to half the load required to cause $\frac{3}{4}$ inch (19.1 mm) of lateral deflection at the ground surface.

4.5 General Testing Requirements: Test equipment shall be adequate to impose anticipated maximum loads. If loading is not carried to failure, the highest value achieved will be considered the maximum load.

5.0 QUALITY CONTROL

5.1 Manufacturing: All products shall be manufactured under an approved quality control program with inspections by an inspection agency accredited by the International Accreditation Service (IAS) or otherwise acceptable to ICC-ES.

5.2 Quality Control Documentation: Quality documentation complying with the ICC-ES Acceptance Criteria for Quality Documentation (AC10) shall be submitted.

6.0 EVALUATION REPORT RECOGNITION

6.1 General: The evaluation report shall include a description of the helical foundation device or system, typical applications, and limitations. The evaluation report shall state that (1) the device or system shall be limited to support of structures in IBC Seismic Design Categories A, B, and C or UBC Seismic Zones 0, 1, and 2, only; (2) the device or system shall not be used in conditions that are indicative of a potential pile corrosion situation as defined by soil resistivity less than 1,000 ohm-cm, pH less than 5.5, soils with high organic content, sulfate concentrations greater than 1,000 ppm, landfills, or mine waste.

System and device descriptions shall include the dimensions of primary components as well as engineering drawings of the product. Any bracket connections to structures shall be prescriptively specified in construction details, including type and condition of structure to be supported, drill holes, bolts, washer plates, field welds, minimum concrete cover, concrete reinforcement, and leveling grout, as applicable. The recommended angle of shaft installation and maximum permissible departure from that angle shall be specified for each bracket. Construction details for bracket connections shall indicate that materials with different corrosion protection coatings shall not be combined in the same system and that helical foundation devices and systems shall not be placed in electrical contact (galvanically isolated) with structural steel, reinforcing steel, or any other metal building components.

A table of allowable capacities (tension, compression, and/or lateral) for all elements (P1, P2, P3, and P4, as applicable) shall be provided with listings for each system or device and all possible combinations and configurations. The evaluation report shall state that the allowable capacity of a helical foundation device or system shall be governed by the least allowable capacity, P1 through P4, as applicable.

If lateral resistance is included in the evaluation report, a table of soil capacity in the lateral direction based on load tests shall be provided for each type of shaft in each test soil condition. The evaluation report shall indicate that soil capacity in the lateral direction needs to be determined by a registered design professional unless the soil conditions for the site in question are generally consistent with soil types described in the evaluation report. For any helical foundation device subject to combined lateral and axial compression or axial tension, the evaluation report shall contain the maximum allowable lateral strength and the maximum allowable axial strength and shall state that the strength of the device is governed by the interaction equation given in the AISC reference standard.

The evaluation report shall provide a discussion of elastic shortening/lengthening, anticipated settlements, and typical elastic deflections, as applicable, depending the end use. The discussion shall contain design values from analysis or load tests.

6.2 Brackets: Bracket capacities, P1, shall include reference to the type of shaft and shall include provisions for, P2, shaft capacity. The table of side load bracket capacities also shall include a list of values or an equation for determining the maximum overturning moment specific to that type of bracket as a function of axial load supported. The allowable capacities of brackets connected to or embedded in concrete shall provide values for systems

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installed in the different concrete strengths that were evaluated. Installation shall be limited to uncracked concrete as defined in the applicable code. Allowable capacities for direct load brackets shall clearly identify the construction details for which those capacities are applicable. For slab support brackets, a table shall be provided showing recommended bracket spacing for support of different slabs under different loading conditions as described in Section 3.10.3. The table of capacities for brackets and shafts shall indicate whether the structure to be supported has to be sideway braced or rotationally fixed based on assumptions used in the design and testing of the product.

6.3 Shafts: Shaft capacities shall be tabulated for each size of shaft for the conditions of being braced or unbraced in soft and firm soils as applicable. The evaluation report shall define these conditions by reference to Chapter 18 of the IBC. Standard penetration resistance blow count ranges for firm and soft soils described in Section 3.11.2.1 of this criteria shall be repeated in evaluation reports. The evaluation report shall state that the shaft capacity of helical foundations in fluid soils shall be determined by a registered professional engineer. For evaluation reports including provisions for lateral resistance, the structural properties of the shaft shall be provided including gross area, section modulus, modulus of elasticity, maximum allowable bending moment, and maximum allowable shear.

6.4 Helices: Helix compression and tension capacities shall be tabulated for each diameter, thickness, edge geometry, pitch, and material strength available. The evaluation report shall indicate that the capacities shall be added together for products with multiple helix plates.

6.5 Soil Capacity: If a soils capacity-to-torque ratio was validated, it shall be listed in the evaluation report along with the equations set forth in this acceptance criteria. Otherwise, the evaluation report shall indicate that soil capacity in compression or tension needs to be determined by a registered design professional. For lateral soil resistance, the evaluation report shall contain a table of capacities for all soil types used in the lateral load testing. The evaluation report shall state that lateral soil resistance shall be determined by a registered design professional for soil conditions that differ from those shown in the table.

6.6 Materials: The evaluation report shall list the material composition, including steel grades, of system and device components. Minimum material specifications for structures to be supported on brackets included in the evaluation report shall be included, as applicable.

6.7 Design: The evaluation report shall describe general procedures for design and application of the helical foundation system or device and state whether bracket capacity is based on a braced or unbraced helical system or device in accordance with IBC Section 1808. An explanation of the structural analysis that shall be performed by the design professional for proper application of the system or device including consideration of the internal shears and moment due to structure eccentricity and maximum span between helical foundations shall be provided. The magnitude of shear and moment forces exerted on the structure due to the connection of the structure to the helical foundation or device shall be provided. The results of this analysis and the structural capacities shall be used to select

a helical foundation system. The evaluation report shall state a minimum helical foundation shaft spacing of four helix plate diameters to avoid group efficiency effects. The minimum embedment depth for various loading conditions shall be included based on analysis and tested conditions. The evaluation report shall indicate that Section 1808 of the IBC shall apply to these products.

6.8 Foundation and Soils Investigation Report: The evaluation report shall indicate that a site-specific foundation and soils investigation report is required for proper application of these products. The foundation and soils investigation report shall address corrosive properties of the soil to ensure that a potential pile corrosion situation does not exist. The foundation and soils investigation report shall address the support conditions for the shaft. The foundation and soils investigation report shall address the axial compression, axial tension, and lateral load soil capacities if values cannot be determined from the evaluation report. The foundation and soils investigation report shall address effects of groundwater and other questionable characteristics.

6.9 Installation: The evaluation report shall note any special training or certification required for installation professionals, equipment required for installation, and a detailed description of proper installation techniques. Requirements and procedures for quality assurance inspection of product installation shall be described, including procedures for field verification of ultimate maximum soil capacity for tension and compression through correlations with final installation torque, as applicable. The evaluation report shall state that the torque induced in the shaft shall not exceed the maximum installation torque. The evaluation report shall state that for tension applications, the pier shall be installed such that the minimum depth from the ground surface to the uppermost helix is 12D, where D is the diameter of the largest helix.

6.10 Special Inspection: For installation, the evaluation report shall state that special inspection in accordance with Section 1704.9 of the IBC or Section 1701.5.11 of the UBC is required. Where on-site welding is required, the evaluation report shall state that special inspection in accordance with Section 1704.3 of the IBC or Section 1701.5.5 of the UBC is required. The evaluation report shall state the items to be observed by the special inspector. At a minimum, these items shall include verification of manufacturer, helical pier and bracket configuration, the installation torque and depth of the foundation, and compliance of the installation of helical foundation system with the approved construction documents and this evaluation report. In lieu of continuous special inspection, periodic special inspection in accordance with IBC Section 1701.6.2 may be permitted when structural observations in accordance with IBC Section 1702, a periodic inspection schedule (prepared by the registered design professional), and evidence of installer training by the report holder are provided to the code official.

6.11 Identification: The evaluation report shall describe the identification method used by the manufacturer as set forth in Section 2.1.4.

6.12 Findings: The evaluation report shall list approved manufacturing facilities and their inspection agencies. ■

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TABLE 1—REFERENCE STANDARD EDITIONS

STANDARD	IBC	UBC
ANSI AF&PA NDS	2005	1991 revised
AISC ASD	AISC 360-05	June 1, 1989
AISC LRFD	AISC 360-05	March 16, 1991
AWS D1.1	2004	1992

TABLE 2—SOIL CAPACITY ANALYSIS/TEST REQUIREMENTS¹

HELIX COMBINATION	NUMBER OF HELICES	SAND	CLAY	HARD BEDROCK	NUMBER OF COMPRESSION TESTS	NUMBER OF TENSION TESTS
Smallest diameter	1	C/T		C	2	1
Largest Diameter	1		C/T	C	2	1
Any two diameters	2	C/T	C/T		2	2
Any three diameters	3	C/T	C/T		2	2
Minimum Number of Tests Required					8	6

¹C = Compression; T = Tension.

TABLE 3—TORQUE CORRELATION CONFORMANCE CRITERIA

CRITERIA	
1	Square shafts with dimensions between 1.5 inches by 1.5 inches and 1.75 inches by 1.75 inches, or round shafts with outside diameters between 2.875 inches and 3.5 inches
2	True helix shaped plates that are normal with the shaft such that the leading and trailing edges that are within 1/4 inch of parallel.
3	Capacity is within normal capacity limits
4	Helix plate diameters between 8 inches and 14 inches with thickness between 3/8 inch and 1/2 inch.
5	Helix plates and shafts are smooth and absent of irregularities that extend more than 1/16 inch from the surface excluding connecting hardware and fittings.
6	Helix spacing along the shaft shall be between 2.4 to 3.6 times helix diameter.
7	Helix pitch is 3 inches ± 1/4 inch.
8	All helix plates have the same pitch.
9	Helical plates are arranged such that they theoretically track the same path as the leading helix.
10	For shafts with multiple helices, the smallest diameter helix shall be mounted to the leading end of the shaft with progressively larger diameter helices above.
11	Helical foundation shaft advancement equals or exceeds 85% of helix pitch per revolution at time of final torque measurement.
12	Helix piers shall be installed at a rate less than 25 revolutions per minute.
13	Helix plates have generally circular edge geometry.

For **SI**: 1 inch = 25.4 mm.

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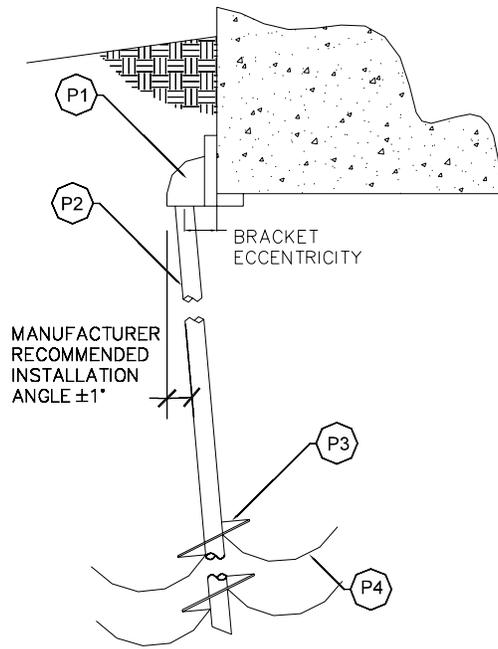


FIGURE 1—TYPE A SIDE LOAD APPLICATION

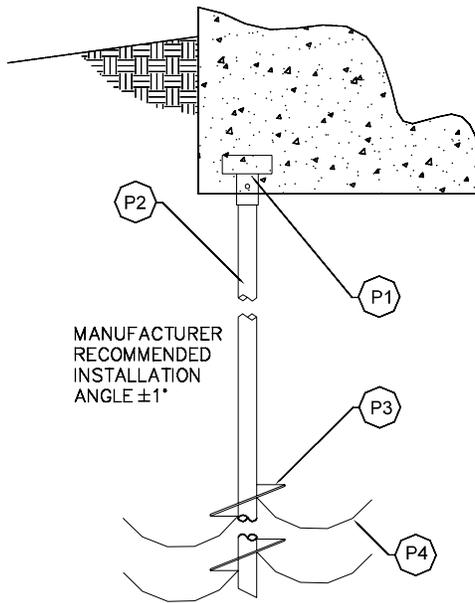


FIGURE 2—TYPE B DIRECT LOAD APPLICATION

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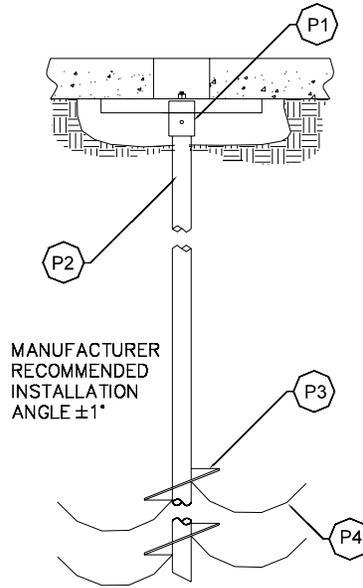


FIGURE 3—TYPE C SLAB SUPPORT APPLICATION

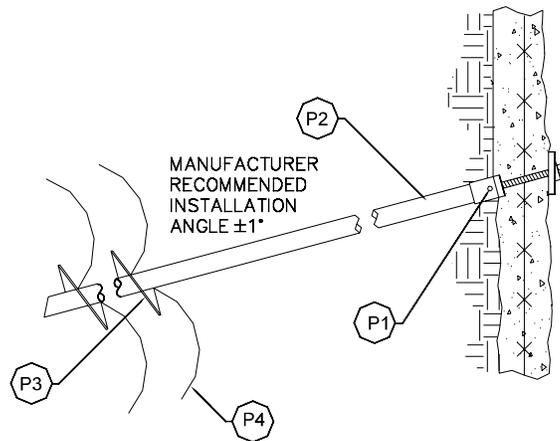


FIGURE 4—TYPE D TENSION ANCHOR APPLICATION

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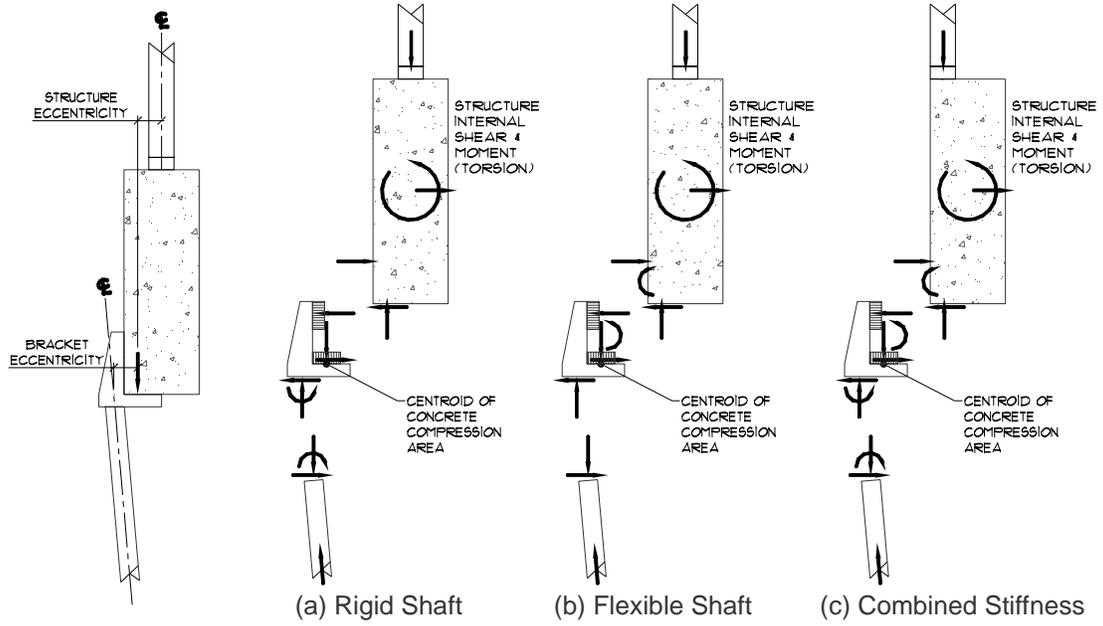
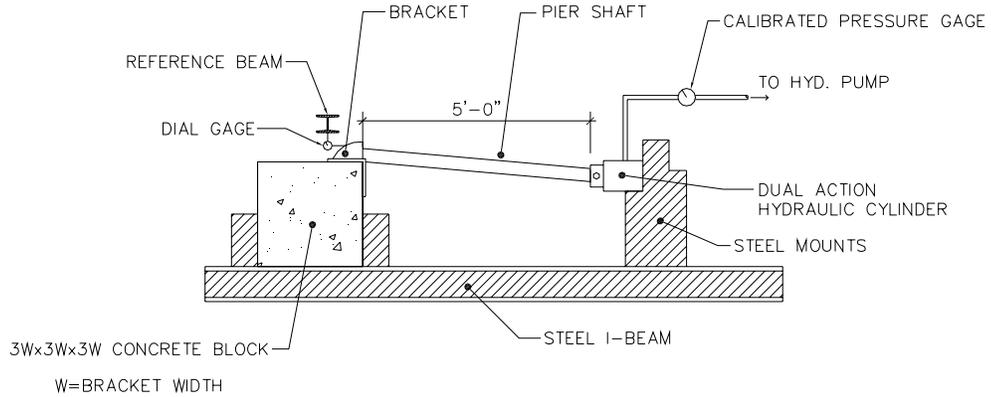


FIGURE 5—TYPE A BRACKET FREE BODY DIAGRAMS



For SI: 1 inch = 25.4 mm.

FIGURE 6—TYPE A BRACKET EXAMPLE LABORATORY TEST SET-UP

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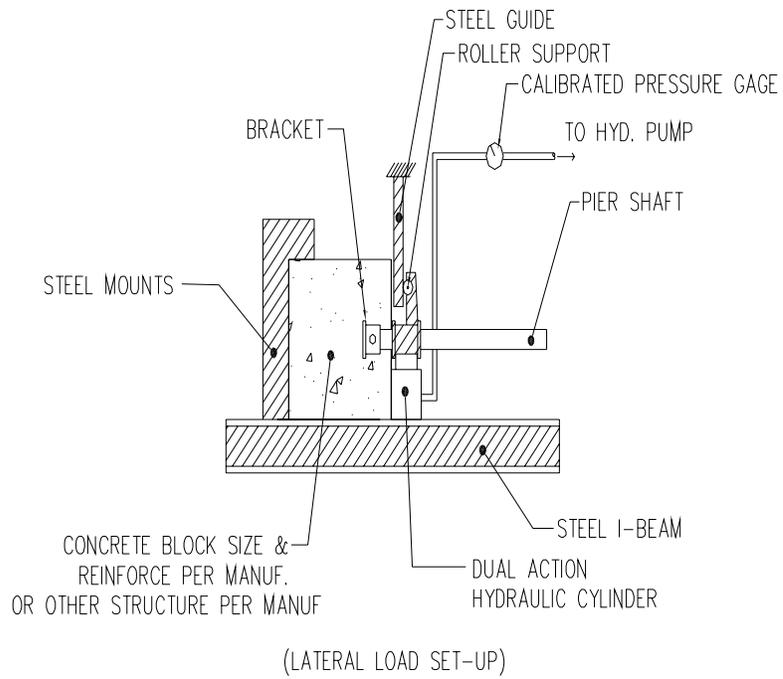
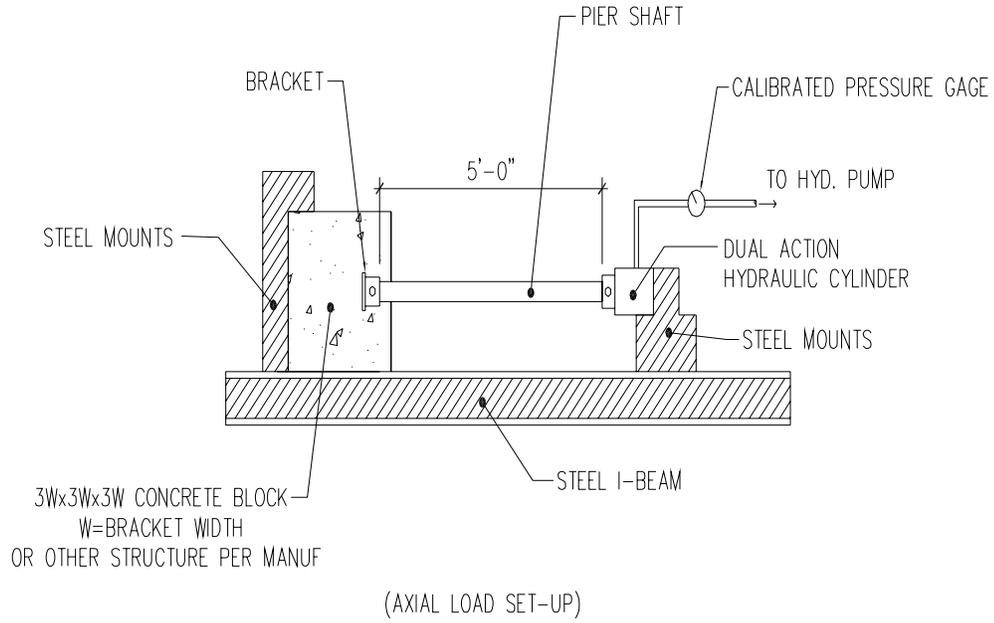
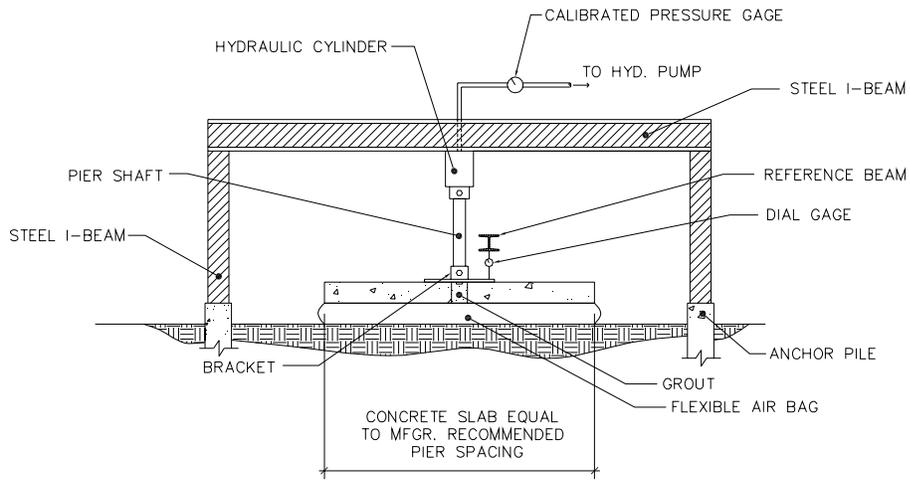


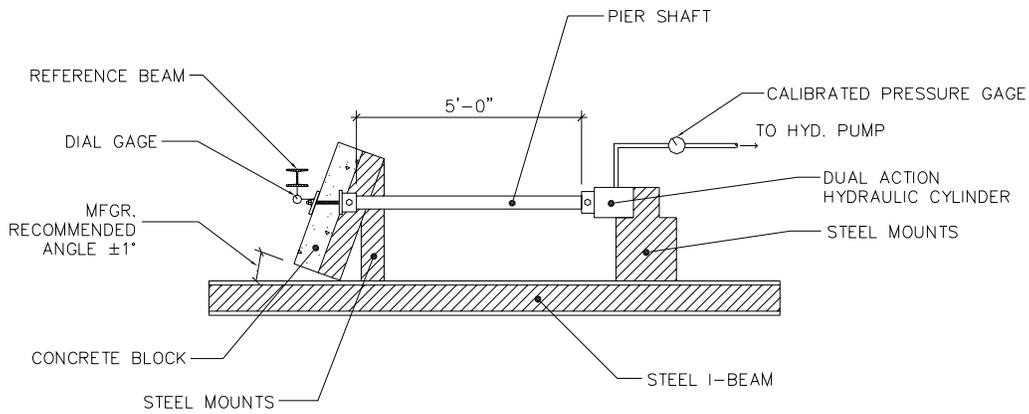
FIGURE 7—TYPE B BRACKET EXAMPLE LABORATORY TEST SET-UP

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For **SI**: 1 inch = 25.4 mm.

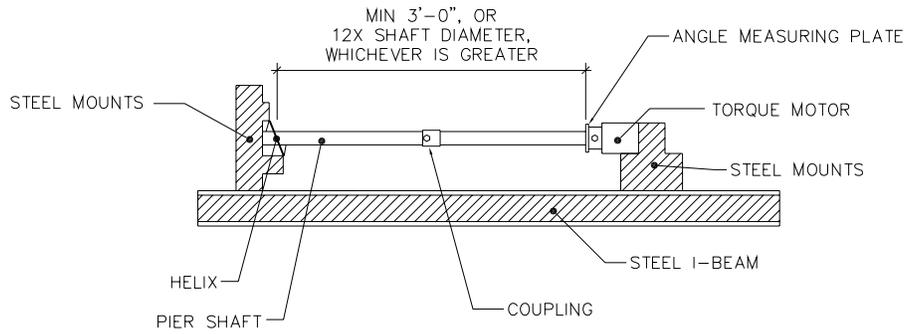
FIGURE 8—TYPE C BRACKET EXAMPLE LABORATORY TEST SET-UP



For **SI**: 1 inch = 25.4 mm.

FIGURE 9—TYPE D BRACKET EXAMPLE TEST SET-UP

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For **SI**: 1 inch = 25.4 mm.

FIGURE 10—SHAFT TORSION EXAMPLE LABORATORY TEST SET-UP

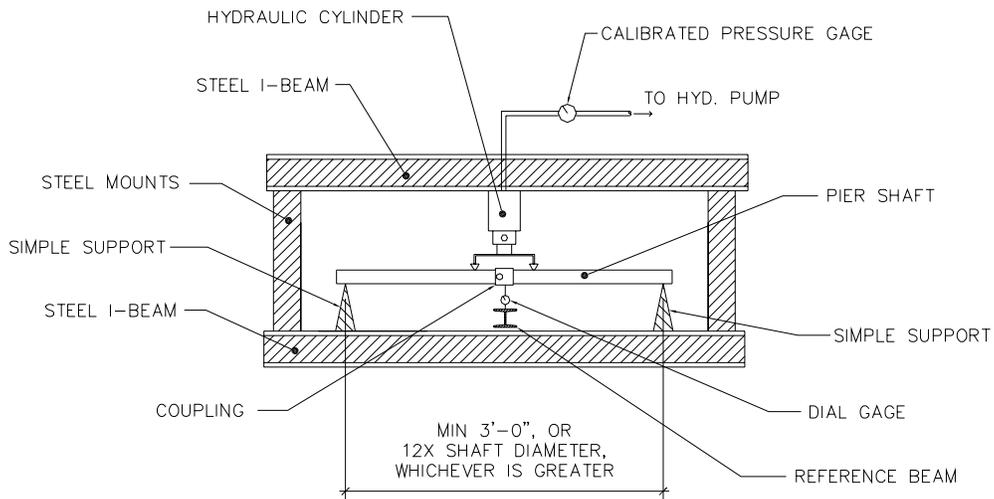


FIGURE 11—SHAFT BENDING EXAMPLE LABORATORY TEST SET-UP

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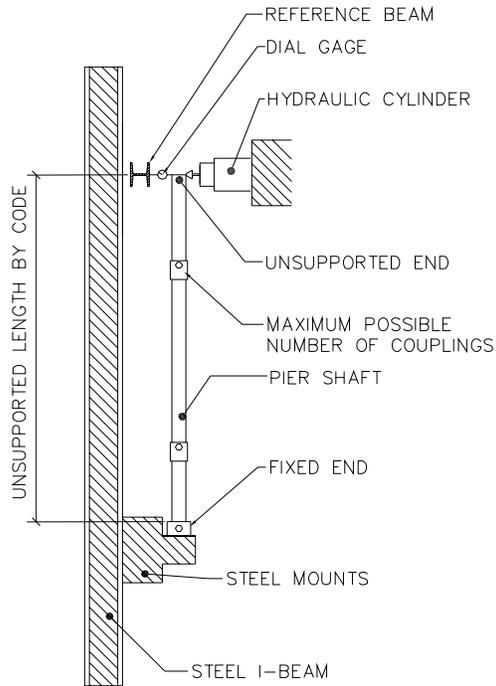


FIGURE 12—COUPLING RIGIDITY EXAMPLE LABORATORY TEST SET-UP

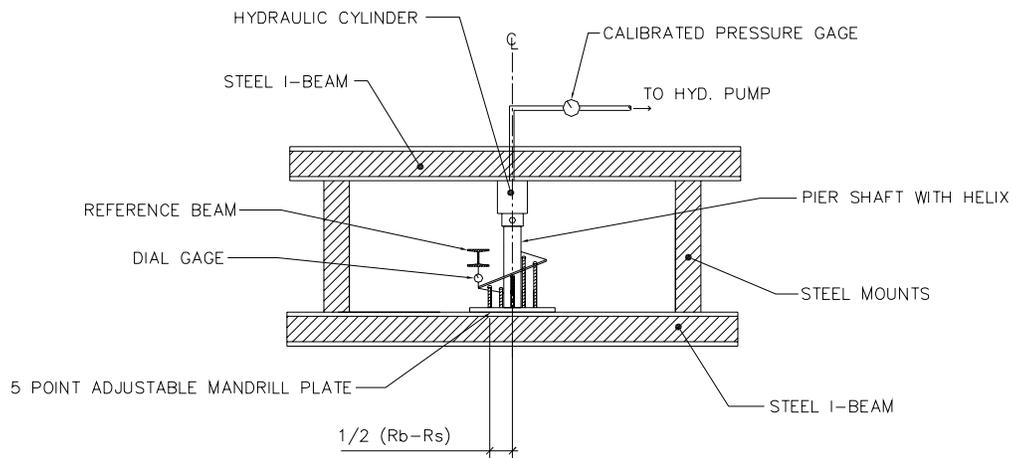


FIGURE 13—HELIX EXAMPLE LABORATORY TEST SET-UP