ICC EVALUATION SERVICE, INC.
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December 20, 2006

TO: **PARTIES INTERESTED IN EVALUATION REPORTS ON HELICAL FOUNDATION SYSTEMS AND DEVICES**

SUBJECT: Proposed Acceptance Criteria for Helical Foundation Systems and Devices, Subject AC358-0207-R1 (BG/RK)

Hearing Information:
Wednesday, February 7, 2007
8:00 a.m.
The Westin Los Angeles Airport
5400 West Century Boulevard
Los Angeles, California 90045
(310) 216-5858

Dear Madam or Sir:

The subject acceptance criteria is on the agenda of the hearing noted above for consideration by the ICC-ES Evaluation Committee. The proposed acceptance criteria is a new acceptance criteria based on a request from a report applicant to establish performance requirements for helical foundation systems and devices (helical piers and foundation brackets).

The proposed acceptance criteria applies to foundation systems used as alternatives to piles in supporting structures. The systems may include brackets used to connect the helical devices to other foundation elements. Evaluation under the proposed acceptance criteria pertains to evaluating the procedures used to determine the strength capacity of the system, for the support of compression, tension, and transverse shear loads. In addition, the systems' load and deformation capacity in the soil may be determined in accordance with the criteria. Provisions for corrosion potential are included, since the devices are limited to structural steel.

ICC-ES staff has the following comments on the proposed acceptance criteria:

1. **Section 1.2, Scope—Loading Direction:** The proposal would not evaluate the system's resistance to loads applied normal to the axis of the shaft. Therefore, resistance to lateral loads applied to a building would be accomplished by the orientation of the shaft to the applied loads with the helical system functioning in tension or compression. Transverse shear resistance would be established where eccentricities occur in the system.

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2. **Section 1.4.5, Special Analysis:** The verification of special analysis results is unclear. If verification includes testing, acceptable correlation levels should be considered. Also, should test results only be permitted in all cases to establish device capacities, or should testing only be limited to certain cases, such as for the Helix (P3)?

3. **Section 3.7, Design Methods, Special Analysis:** This section is not clear as to whether the value of P' determined in Eq-5 is applicable to allowable stress design or load and resistance factor design. The proposed design capacities are oriented to steel capacities of the devices. The question arises as to whether the analysis needs to consider the capacities of the connected materials, such as concrete.

4. **Section 3.9, Corrosion:** The minimum zinc coating weight for the devices is unclear and needs to be established. The means to construct test specimens with the reduced design thickness, T_d, is unclear. The proposed corrosion methodology is applicable to structural steel only. The criteria needs to establish corresponding corrosion provisions for other system constituents, such as welds and bolts.

5. **Section 3.13.1, Axial Capacity:** This section omits tests of shafts with multiple helices. No information was supplied supporting the theory that soil capacity of a shaft with multiple helices can be taken as the multiple of a single helix capacity. The proposal is not clear as to whether soil capacities need to be done in saturated soils or not, a likely condition. The tests are proposed to be done at the National Geotechnical Test Site only, but torque correlation tests outlined in Section 3.13.2 are proposed to be done as field tests at any site with an established soil profile. The staff questions whether the two test regimens should be subject to similar requirements.

6. **Section 3.13.2, Torque Correlations:** Eq-8 is presented as valid for compressive loads only. Table 2, though, requires correlation testing for tension and compression. The determination of tension capacity from testing is not clear. Also, Eq-9 is represented as valid for allowable stress design only. Calibration to load and resistance factor design is needed.

7. **Section 3.13.2.1, Conforming Products:** As indicated in Comment 6, the procedure for correlating tests is represented as valid for allowable stress design only. Calibration to load and resistance factor design is needed.

8. **Section 4.1, P1 Bracket Capacity:** As the bracket capacity is dependent on the concrete characteristics, the question is raised as to whether tests should be in different concrete types, including cracked concrete.

9. **Section 4.4.2.1, Transverse Shear Load Tests:** The ASTM standard in the second paragraph needs to be disclosed.

In addition to the codes and standards described in Section 1.3 of the proposed criteria draft, research references used in the development of the proposed acceptance criteria include the following:

1. Hoyt, R.M. and Clemence, S.P. (1989) “Uplift Capacity of Helical Anchors in Soil,” Proceedings of the 12th International Conference on Soil Mechanics and Foundation Engineering, Rio de Janeiro, Brazil.

2. Puri, V.K., Stephenson, R.E., Dziedzic, E., and Goen, L. (1984) “Helical Anchor Piles Under Lateral Loading,” Laterally Loaded Deep Foundations: Analysis and Performance, ASTM Special Technical Publication 835, Langer, J.A., Mosley, E.T., Thompson, C.D. Eds., pp. 194-213.

3. Perko, H.A. (2003) “Lateral Capacity and Buckling Resistance of Helix Pier Foundations,” Proceedings of the Helical Foundations and Tiebacks Technology Seminar, Deep Foundation Institute, Cincinnati, OH.

4. Perko, H.A. (2000) “Energy Method for Predicting Installation Torque of Helical Foundations and Anchors,” New Technological and Design Developments in Deep Foundations, Proceedings of GeoDenver 2000, N.D. Dennis, Jr., R. Castelli, and M.W. O’Neill, Eds., Geotechnical Special Publication, ASCE Press, Reston, VA.

5. Elias V. (2000) “Corrosion/Degradation of Soil Reinforcement for Mechanical Stabilizer Earth Walls and Reinforced Soil Slopes,” Report No. FHVA-NHI-00-044.

6. Helmers, Duncan, and Filz (1997) “Use of Ultimate Load Theories for Design of Drilled Shaft Soundwall Foundations,” Technical Report, Virginia Tech.

7. Romanoff, M. (1972) “Corrosion of Steel Pilings in Soil,” National Bureau of Standards Monograph 127, NBS Papers on Underground Corrosion of Steel™ Piling.

8. Ghaly and Hanna (1992) “Stresses and Strains Around Helical Screw Anchors in Sand,” Soils and Foundations, Vol. 32, No. 4, 27-42, Japanese Society of Soil Mechanics and Foundation Engineering.

You are cordially invited to submit written comments, or to attend the Evaluation Committee hearing and present verbal comments. Written comments will be forwarded to the committee, **prior to the hearing**, if received by **January 23, 2007**. If the deadline is missed, you must provide 35 copies of the submittal material, collated, stapled and three-hole punched, to the Los Angeles business/regional office before the committee meeting. Your consideration in providing written responses by the deadline would be greatly appreciated. Consideration of written comments and presentations of a significant nature received the week of the hearing or at the hearing may be delayed until a future meeting as the committee and staff may not have adequate time for review.

NEW FOR THE FEBRUARY 2007 MEETING! On a trial basis, starting with the February 2007 Evaluation Committee meeting, comments from interested parties that are submitted in response to proposed acceptance criteria will be posted on the ICC-ES web site prior to the meeting. Postings will occur shortly after the comment deadline (January 23, 2007). Staff memos responding to some of the

comments, and comments received after the January 23 deadline, will be posted on February 1, 2007.

The purpose for posting the comments prior to the meeting is to help interested parties be better prepared to discuss the issues at the meeting.

Any written material submitted for committee consideration will be available for public distribution as set forth in Section 2.7 of the Rules of Procedure for the Evaluation Committee (copy enclosed).

Visual aids (including, but not limited to, charts, overhead transparencies, slides, videos, or presentation software) for viewing at meetings will be permitted only if the presenter provides to ICC-ES, before the presentation, a copy of the visual aid(s) in a medium that can be retained by ICC-ES with its record of the meeting, and that can also be provided to interested parties.

Your cooperation is requested in forwarding to the Los Angeles business/regional office all material directed to the Evaluation Committee. Parties interested in the deliberations of the committee should refrain from communicating, whether in writing or verbally, with committee members regarding agenda items. The committee reserves the right to refuse communications that do not comply with this request.

Newly approved acceptance criteria may involve test methods or test protocols that are not currently included in the scope of testing services offered by accredited testing laboratories. As noted in the ICC-ES Rules of Procedure for Evaluation Reports, the scope of the laboratory's accreditation must include the type of testing that is to be reported to ICC-ES. We encourage accredited laboratories to expand their scopes of accreditation to include testing under newly approved acceptance criteria. Please note that testing laboratories must be accredited by the International Accreditation Service (IAS) or by another accreditation body that is a signatory to the International Laboratory Accreditation Cooperation Mutual Recognition Arrangement. For further information, please contact IAS at (562) 699-0541, extension 3309, or send an e-mail to pmccullen@iasonline.org.

If you have any questions, please contact the undersigned at (800) 423-6587, extension 3260, or Russ Krivchuk, P.E., senior staff engineer, at extension 3275. You may also reach us by e-mail at es@icc-es.org.

Yours very truly,

Brian C. Gerber

Brian C. Gerber, S.E.
Principal Structural Engineer

BG/RK/ll

Enclosures

cc: Evaluation Committee

ICC EVALUATION SERVICE, INC., RULES OF PROCEDURE FOR THE EVALUATION COMMITTEE

1.0 PURPOSE

The purpose of the Evaluation Committee is to monitor the work of ICC-ES, in issuing evaluation reports; to evaluate and approve acceptance criteria on which evaluation reports may be based; and to sponsor related changes in the applicable codes.

2.0 MEETINGS

2.1 The Evaluation Committee shall schedule meetings that are open to the public in discharging its duties under Section 1, subject to Section 3.

2.2 All scheduled meetings shall be publicly announced.

2.3 Two-thirds ($^2/_3$) of the voting Evaluation Committee members shall constitute a quorum. A majority vote of members present is required on any action.

2.4 In the absence of the nonvoting chairman-moderator, Evaluation Committee members present shall elect an alternate chairman from the committee for that meeting. The alternate chairman shall be counted as a voting committee member for purposes of maintaining a committee quorum and to cast a tie-breaking vote of the committee.

2.5 Minutes of the meetings shall be kept.

2.6 An electronic audio record of meetings shall be made by ICC-ES; no other audio, video, electronic or stenographic recordings of the meetings will be permitted. Visual aids (including, but not limited to, charts, overhead transparencies, slides, videos, or presentation software) viewed at meetings shall be permitted only if the presenter provides ICC-ES before presentation with a copy of the visual aid in a medium which can be retained by ICC-ES with its record of the meeting and which can also be provided to interested parties requesting a copy. A copy of the ICC-ES recording of the meeting and such visual aids, if any, will be available to interested parties upon written request made to ICC-ES together with a payment as required by ICC-ES to cover costs of preparation and duplication of the copy. These materials will be available beginning five days after the conclusion of the meeting but will no longer be available after 30 days have elapsed from the conclusion of the meeting.

2.7 Parties interested in the deliberations of the committee should refrain from communicating, whether in writing or verbally, with committee members regarding agenda items. All written communications and submissions regarding agenda items should be delivered to ICC-ES. All such written communications and submissions shall be considered nonconfidential and available for discussion in open session of an Evaluation Committee meeting, and shall be delivered at least ten days before the scheduled Evaluation Committee meeting if they are to be forwarded to the committee. Correspondence received by ICC-ES will not be released to any party, except to the Evaluation Committee, prior to the meeting without permission of the author. The committee reserves the right to refuse recognition of communications which do not comply with the provisions of this section. All such communications and submissions will be available from ICC-ES upon written request and payment of costs associated with duplication. The materials will be available beginning five days after the conclusion of the meeting but will no longer be available after 30 days have elapsed from the conclusion of the meeting.

3.0 CLOSED SESSIONS

Evaluation Committee meetings shall be open except that the chairman may call for a closed session to seek advice of counsel.

4.0 ACCEPTANCE CRITERIA

4.1 Acceptance criteria are established by the committee to provide a basis for issuing ICC-ES evaluation reports on products and systems under codes referenced in Section 2.0 of the Rules of Procedure for Evaluation Reports. They also clarify conditions of acceptance for products and systems specifically regulated by the codes.

Acceptance criteria may involve a product, material, method of construction, or service. Consideration of any acceptance criteria must be in conjunction with a current and valid application for an ICC-ES evaluation report, an existing ICC-ES evaluation report, or as otherwise determined by the Evaluation Committee.

4.2 Procedure:

4.2.1 Proposed acceptance criteria shall be developed by the ICC-ES staff and discussed in open session with the Evaluation Committee during a scheduled meeting, except as permitted in Section 5.0 of these rules.

4.2.2 Proposed acceptance criteria shall be available to interested parties at least 30 days before discussion at the committee meeting.

4.2.3 The committee shall be informed of all pertinent written communications received by ICC-ES.

4.2.4 Attendees at Evaluation Committee meetings shall have the opportunity to speak on acceptance criteria listed on the meeting agenda, to provide information to committee members.

4.3 Approval of acceptance criteria shall be as specified in Section 2.3 of these rules.

4.4 The action of the Evaluation Committee may be appealed in accordance with the ICC-ES Rules of Procedure for Appeal of Acceptance Criteria.

5.0 COMMITTEE BALLOTING FOR ACCEPTANCE CRITERIA

5.1 Acceptance criteria may be issued without a public hearing following a 45-day public comment period and a majority vote for approval by the Evaluation Committee when, in the opinion of ICC-ES staff, one or more of the following conditions have been met:

1. The subject is nonstructural, does not involve life safety, and is addressed in nationally recognized standards or generally accepted industry standards.

2. The subject is a revision to an existing acceptance criteria that requires a formal action by the Evaluation Committee, and public comments raised were resolved by staff with commenters fully informed.

3. Other acceptance criteria and/or the code provide precedence for the revised criteria.

5.2 Negative votes must be based upon one or more of the following, for the ballots to be considered valid and require resolution:

a. *Lack of clarity*: There is insufficient explanation of the scope of the acceptance criteria or insufficient description of the intended use of the product or system; or the acceptance criteria is so unclear as to be unacceptable. (The areas where greater clarity is required must be specifically identified.)

b. *Insufficiency*: The criteria is insufficient for proper evaluation of the product or system. (The provisions of the criteria that are in question must be specifically identified.)

c. *The subject of the acceptance criteria is not within the scope of the applicable codes*: A report issued by ICC-ES is intended to provide a basis for approval under the codes. If the subject of the acceptance criteria is not regulated by the codes, there is no basis for issuing a report, or a criteria. (Specifics must be provided concerning the inapplicability of the code.)

d. *The subject of the acceptance criteria needs to be discussed in a public hearings*. The committee member requests additional input from other committee members, staff or industry.

5.3 An Evaluation Committee member, in voting on an acceptance criteria, may only cast the following ballots:

- Approved
- Approved with Comments
- Negative: Do Not Proceed

6.0 COMMITTEE COMMUNICATION

Direct communication between committee members, and between committee members and an applicant or concerned party, with regard to the processing of a particular acceptance criteria or evaluation report shall take place only in a public hearing of the Evaluation Committee. Accordingly:

6.1 Committee members receiving an electronic ballot should respond only to the sender (staff). Committee members who wish to discuss a particular matter with other committee members, before reaching a decision, should ballot accordingly and bring the matter to the attention of ICC-ES staff, so the issue can be placed on the agenda of a future committee meeting.

6.2 Committee members who are contacted by an applicant or concerned party on a particular matter that will be brought to the committee will refrain from private communication and will encourage the applicant or concerned party to forward their concerns through the ICC-ES staff in writing, and/or make their concerns known by addressing the committee at a public hearing, so that their concerns can receive the attention of all committee members.■

Effective November 6, 2006

PROPOSED ACCEPTANCE CRITERIA FOR HELICAL FOUNDATION SYSTEMS AND DEVICES

AC358

Proposed December 2006

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.

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 proposed in this document, and otherwise meet the applicable performance requirements of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria proposed in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise meet the applicable performance requirements 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 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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**PROPOSED ACCEPTANCE CRITERIA FOR
HELICAL FOUNDATION SYSTEMS AND DEVICES**

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 compression and tension loads, and transverse shear loads resulting from eccentricities in the system. 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 a 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 hot-dip zinc galvanized 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).

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

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

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

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

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

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

1.3.18 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 Helical Foundation System: A factory-manufactured steel foundation designed to resist axial compression, tension loads from structures, consisting of a central shaft with one or more helical-shaped bearing plates, extension shafts, and a bracket that allows 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.

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

1.4.3 Transverse Shear: Forces acting on a helical foundation system or device in a direction that is perpendicular to the longitudinal direction of the shaft, typically resulting in eccentricities in the system.

1.4.4 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.

1.4.5 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: Complete information pertaining to the helical foundation systems or device, including material specifications and scaled 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.

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, and tension loads and transverse shear loads resulting from eccentricities in the system, 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.

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 pull-out in accordance with Section 3.13.

3.6 Determination of Allowable Capacities: The design capacities of helical foundation elements P1, P2, and P4 for each application shall be evaluated based on requirements described in the IBC or UBC, and associated referenced standards. Alternatively, where specified herein, evaluation shall be based on special analysis, which shall be verified through load testing. The design capacity P3 shall be determined using special analysis and requirements in Section 3.12.

3.7 Design Methods: For conventional design, either Allowable Stress Design (ASD) or Load and Resistance Factor Design (LRFD) methods may be used. When using the ASD method, the design capacity, P', shall be taken as the allowable strength, P_a, and shall be determined in accordance with the AISC-360 (Eq-3). When using the LRFD method, the design capacity, P', shall be taken as 0.7 times the design strength, ϕP_n, and shall be determined in accordance with the AISC-360 (Eq-4). Where special analysis is used, the 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_{ult}) (Eq-5).

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

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

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

3.8 Capacity Limits: For conventional design, the maximum design capacity of helical foundation systems and devices is 60 kips (133.5 kN) in axial tension and axial compression and 6 kips (26.7 kN) in transverse shear. Helical foundation systems or devices with 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 steel with galvanized coatings. Fasteners and welds shall be stainless steel in order to be considered galvanized. All components in the system or device shall be zinc-coated by the hot-dip method in accordance with ASTM A 123 or ASTM A 153, as applicable. In order to be considered corrosion-resistant, powder coatings shall meet criteria established in ICC-ES AC228 and the coating thickness shall be at least 450 μm (0.018 in). 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 average sacrificial thickness given below 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

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

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

Galvanized steel: $T_s = 25\ t^{0.65}$ = 318 μm (0.013 in)

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

Powder coated steel

Life of powder coating = 16 yrs (hence, t = 50-16 = 34 years), T_s = 40 $t^{0.80}$ = 671 μm (0.026 in)

Corrosion loss shall be accounted for regardless of whether devices are below or above ground or embedded in concrete. Galvanized steel, powder coated steel, and bare steel components shall not be combined in the same system, and 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 compressive load, direct compressive 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. Brackets may be evaluated for compression, tension, and/or transverse shear strengths. The angle of the shaft with respect to the bracket recommended by the installation instructions 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 pier shaft inclination relative to vertical shall be accounted for by incorporating a transverse shear component of forces in the analysis of the bracket, pier shaft, and bracket connections. The shaft and the bracket shall be attached by a mechanical connection.

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. Rotational moments caused by load eccentricity shall be subdivided into two components, bracket eccentricity and structure eccentricity, as illustrated in Figure 5. The shaft, 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. Type A brackets shall only be used to support structures that braced as defined in IBC Section 1808.2.5. The strength of bracket components, shafts and connections shall be evaluated based on the following criteria.

$$G = M_p/M_b \quad \text{(Eq-7)}$$

where:

M_b = Moment capacity of the connection of the bracket to the structure (in-lb or N-mm).

M_p = Moment capacity of the pier shaft or the moment capacity of the connection of the pier shaft to the bracket, whichever is less (in-lb or N-mm).

If $G > 10$ Method a applies.

If $G < 0.1$ Method b applies.

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

The moment capacity of the pier shaft, M_p, may be increased by reinforcing the top section of shaft with an outer sleeve, T-pipe, or other means. The reinforced moment capacity of the shaft, M_{pt}, shall be limited to $2M_p$. The reinforcing shall extend to a depth below the base of the bracket equal to or greater than $4(1 - M_p/M_{pt})$(feet) {$1219(1 - M_p/M_{pt})$ (mm)} in soft soils or $2(1 - M_p/M_{pt})$(feet) {$610(1 - M_p/M_{pt})$ (mm)} in firm soils. Firm and soft soils are defined in Section 3.11.2.1. For reinforced shafts, M_{pt} may be substituted for M_p in the formula for G above.

3.10.1.1 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.

3.10.1.2 Method b: Flexible Shaft: This method of evaluation assumes the 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 load is 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.

3.10.1.3 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.

3.10.1.4 Connection to the Structure: 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 mass of structural plain concrete, semi-infinite in extents, 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, normal-weight concrete with a 28-day compressive strength of 2,500 psi (17.22 MPa) shall be considered. 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 are illustrated in Figure 2 and support compressive loads that are concentric with the primary axis of the helical foundation shaft. 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 sidesway braced. The structure shall provide lateral restraint equal to or greater than 0.4 percent of the allowable axial load to be considered sidesway 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. A free body diagram of the bracket based on this method is shown in Figure 6 (Method 1).

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. A free body diagram of the bracket based on this method is shown in Figure 6 (Method 2).

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, connections to concrete structures shall be evaluated for normal-weight concrete with a 28-day 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, 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 loads concentrically. 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 under 40 psf (1915 Pa) and 100 psf (4788 Pa) uniform live load. At a minimum, evaluation shall include 4-, 6-, and 8-inch-thick (102, 152, and 203 mm), unreinforced slabs comprised of normal-weight concrete with minimum 28-day compressive strength of 2,500 psi (17.22 MPa).

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 transverse shear 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 (compression, tension, transverse shear) on any component of a bracket or bracket/shaft system evaluated using Special Analysis and for brackets exceeding Normal Capacities. Where tests are required for verification of transverse shear resistance, tests shall be conducted to verify transverse shear in all directions for which transverse shear 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 transverse shear.

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 transverse shear resistance with consideration of combined transverse shear and axial loading. Evaluation of shafts shall include connections between shafts. All shaft connections shall be made via a mechanical connection.

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, 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. 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, plus the amounts specified in IBC Section 1808.2.9.2 unless determined otherwise by Special Analysis. 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 bracket connectivity as defined in Section 3.10. All Type A brackets shall be considered pinned (laterally braced, rotationally free). Type B brackets shall be considered as either pinned or free depending on whether they are sidesway braced. Slenderness ratio limitations as specified by the AISC referenced standards do not apply.

3.11.2.3 Coupling Rigidity: To account for coupling rigidity, the eccentricity of the axial compressive load applied to the shaft shall be increased by a distance, $n \cdot e_c$, 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 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 torque from the sample population. Torsional strength need not be evaluated for corrosion losses.

3.11.4 Transverse Shear Resistance: Transverse shear 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 transverse shear 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 in accordance with Section 3.7.

3.11.6 Combined Stresses: Shaft evaluation shall include combined stresses. Combinations of tension, compression, bending, and transverse shear 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 explained previously. 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 lease 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 **Transverse Shear:** The determination of the transverse shear capacity of the helix is not permitted. Transverse shear capacity of a helical foundation system is not significantly affected by the presence of helix bearing plates.

3.12.2 **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 results 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 conjunction with shaft torsion testing in accordance with Section 4.2.2.

3.13 **P4 Soil Capacity:** Soil capacity includes the tension, compression, and/or transverse shear 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 shall be conducted to verify the axial capacity on a representative number of specimen installed to refusal in bedrock. 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 pier and all full-scale axial load tests exceed the allowable capacity of the system by a factor or safety of at least 1.5.

At least two specimens of each type of pier 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 the National Geotechnical Test Site at Colorado State University in Fort Collins, Colorado. Additional information on testing is provided in Section 3.13.5. If torque correlations are not provided, the evaluation report shall state that soil capacity shall be determined by a registered professional engineer for each site.

3.13.2 Torque Correlations: Evaluation reports may include a correlation between final installation torque, T, and ultimate axial capacity, Q, given by

$$Q = K_t T$$

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

$$Q_a = 0.5\,Q$$

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 product is conforming or nonconforming. Separate torque correlations are required for shafts with differing geometry and outside dimension 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 1.

3.13.2.1 Conforming Products: Products shall be considered conforming provided they comply 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 - $K_t = 10$ ft^{-1}
2.875-inch O.D. round shafts - $K_t = 9$ ft^{-1}
3.0-inch O.D. round shafts - $K_t = 8$ ft^{-1}
3.5-inch O.D. round shafts - $K_t = 7$ 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 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 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 Products: Products 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 products 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 products, at least eight additional field tests shall be conducted in compression and six additional tests shall be conducted in tension in addition to those 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_f/Q, where Q_f is ultimate soil capacity determined through full-scale field tests and Q is ultimate 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_f/Q is equal to 1.0. The K_t value shall be considered valid if 94 percent of the data have a Qf/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 Transverse Shear Resistance: Allowable soil capacity in transverse shear shall be determined through load tests on a representative number of specimen 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 pier 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 stiff 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 report by a registered design professional. Additional information on testing is provided in Section 3.13.4. Allowable soil capacity for different specimen in different soil categories shall be tabulated in the evaluation report. The evaluation report shall contain a statement that soil capacity for transverse shear 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: Compressive, tensile, and transverse shear allowable 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 transverse shear 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 transverse shear resistance shall be conducted in accordance with Section 4.4.2. Tension and compression verification load tests are required to be conducted at the National Geotechnical Test Site at Colorado State University in Fort Collins, Colorado. 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 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. 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 5-foot section of pier shaft secured to the bracket in a manner that duplicates actual field conditions. The loaded end of the shaft can be rotationally fixed. Axial load shall be applied in the direction of the longitudinal axis of the pier shaft. Any eccentricity inherent in the bracket configuration and manufacturer-recommended angle of 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 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 strength using the equations provided in Section 3.7, 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. The connection of the bracket to the fixture shall be in accordance with manufacturer's installation instructions. Load shall be applied to the bracket using a 60-inch-long (1524 mm) section of pier shaft secured to the bracket in a manner that duplicates actual field conditions. The loaded end of the shaft can be rotationally fixed. Axial load shall be applied in the direction of the longitudinal axis of the pier shaft. Any inclination of the shaft with respect to the structure shall be modeled to match the anticipated design purpose.

4.1.2.2 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 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 strength and the equations provided in Section 3.7, whichever formula results in a lower value. If a concrete structure is used in the load test, the strength of the concrete shall be checked following the procedures explained 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 dimensions equal to the manufacturer's recommended pier spacing for that thickness slab and anticipated loading. The slab support bracket and a section of pier shaft shall be mounted in an inverted fashion over the slab. 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 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 strength and the equations provided in Section 3.7, whichever formula results in the lowest value. The compressive strength of the concrete shall be verified using 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 manufacturer 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. Deflection of the anchor bracket shall be measured with a dial gauge. Load shall be determined with a calibrated load cell. The length of 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 strength and the equations provided in Section 3.7, whichever formula results in a lower value. If applicable, the strength of the concrete shall be verified following 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 load to the specimen in the axial direction. The coupling connection shall be done in accordance with manufacture specific published recommendations. Direction of loading shall be coaxial with the longitudinal axis of the pier. The testing apparatus shall provide of 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 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 strength of the specimen. Each load increment shall be held for a minimum of one minute. The specimen shall be loaded to failure. 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 connection deformation, failure mode, etc. shall be reported. Yield strength and ultimate 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 strength and the equations provided in Section 3.7, whichever formula 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 shaft diameter; 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 rigidly 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 angle of twist.

4.2.2.2 **Procedure:** Torque versus angle of twist shall be monitored and recorded at regular intervals of 6,000 in-lbs (67 N-m). Ultimate torsion resistance shall be defined as that required to achieve 0.5 revolution per foot (0.15 revolution per meter) of shaft length, that which causes failure of the shaft or coupling, or that which damages the coupling to an extent that it cannot be decoupled effectively, 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. The shaft specimen shall be at least 60 inches (1524 mm) long or 12 diameters, whichever is greater, and shall have a coupling 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 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 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 ultimate strength and the equations provided in Section 3.7, whichever formula 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 arranged in a load frame with one end fixed and the other end unsupported. A vertical load shall be applied to the unsupported end of the shaft.

4.2.4.2 Procedures: A vertical load equal to 4 percent of the allowable compression load on the helical pier 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.

4.3 P3 Helix Capacity:

4.3.1.1 Setup: Helix capacity tests shall be performed by placing a short section of shaft with helix in a laboratory load frame. The helix plate shall bear on an adjustable 5-pin mandrill or 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, minus the radius of the shaft, R_s. 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. Ultimate strength of the helix shall be the peak load sustained by the helix. The allowable strength of the helix shall be determined from the ultimate strength in accordance with Section 3.7.

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 either ASTM D 1143 or ASTM D 3689. The quick load test procedure 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 pier depth and final installation torque achieved shall be reported. Torque should be measured with 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 pier shall be installed such that the minimum depth from the ground surface to the uppermost helix is 144 inches (36 576 mm).

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 pier test sites. Ultimate load capacity shall be that which is achieved when plunging of the helix blade occurs or when net deflection exceeds 10 percent of the helix blade diameter, whichever occurs first. Net deflection shall be total deflection minus shaft elastic shortening. For multiple helix configurations, the average helix diameter shall be used in this criterion.

4.4.2 Transverse Shear Load Tests:

4.4.2.1 Setup: Transverse shear load tests shall be conducted in accordance with ASTM D 3966. These tests can be performed in two ways. If verification of transverse shear resistance of brackets is required, the test setup shall consist of a helical foundation with a bracket at 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 transverse shear load is applied to the structure being supported immediately above the bracket elevation. Depending on whether 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 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 pier shaft extending a minimum of 12 inches (304.8 mm) from the ground surface. Transverse shear load shall be applied to the pier shaft immediately above the ground surface. Depending on whether the pier 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 ____________________.

Bracket and helical foundation installation shall be done in accordance with the standards set forth in manufacture specific published recommendations. All test piers shall be installed as close to the recommended angle of installation for the bracket type as possible. Where brackets are not used, the shaft shall be installed as close to vertical as possible. The minimum depth of the uppermost helix shall be 180 inches (54 864 mm) unless the product is only available in a shorter length.

4.4.2.2 Procedures: For tests including brackets or shafts that are nonsymmetrical, separate specimens shall be loaded in all transverse shear 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 $^{3}/_{4}$ inch (19.1 mm) of lateral deflection at the ground surface.

4.5 General Testing Requirements: Test equipment shall be adequate to impose anticipated ultimate loads. If loading is not carried to failure, the highest value achieved will be considered the ultimate 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 Manual: A quality control manual complying with the ICC-ES Acceptance Criteria for Quality Control Manuals (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, only; (2) the device or system shall not be used in conditions that are not 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 with structural steel or reinforcing steel.

A table of allowable capacities (tension, compression, and/or transverse shear) 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.

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 different concrete strengths that were evaluated. 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 sidesway braced or rotationally fixed based on assumptions used the design and testing of the product.

Shaft capacities shall be tabulated for each size of shaft for the conditions of fully supported and unsupported in soft and firm soils. 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 contained in 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 transverse shear, 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.

Helix 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.

If a 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.

If transverse shear resistance is included in the evaluation, a table of soil capacity in transverse shear 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 transverse shear needs to be determined by a registered design professional unless the soil conditions for the site in question are generally consistent with test sites.

The evaluation report shall provide a discussion of elastic shortening/lengthening, anticipated settlements, and typical elastic deflections. The discussion shall contain measured values from load tests.

6.2 Materials: Helical products shall be manufactured from carbon steel, with optional hot-dip zinc galvanized or powder coatings. 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. All material specifications shall be traceable to ASTM, ACI, NDS, AISC, UBC, or IBC requirements. Material composition, grade, and sizes of bolts and fasteners shall be based on criteria in AISC or ANSI requirements.

6.3 Design: The evaluation report shall describe general procedures for design and application of the helical foundation system or device. The evaluation report shall indicate that a site-specific geotechnical report is required for proper application of these products. The geotechnical report shall address corrosive properties of the soil to ensure that a potential pile corrosion situation does not exist. The geotechnical report shall address the support conditions for the shaft. The geotechnical report shall address the axial and transverse shear soil capacity if it cannot be determined from the evaluation report.

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 shear 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 evaluation report shall recommend a minimum pier spacing of four helix plate diameters to avoid group efficiency effects. The evaluation report shall indicate that Section 1807 of the IBC shall apply to these products.

6.4 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 soil capacity for tension and compression through correlations with final installation torque, as applicable.

6.5 Special Inspection: 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.

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

6.7 Findings: The evaluation report shall list approved manufacturing facilities and quality control inspection agencies.■

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TABLE 1—REFERENCE STANDARD EDITIONS

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

TABLE 2—SOIL CAPACITY ANALYSIS/TEST REQUIREMENTS

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

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	Pier 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.

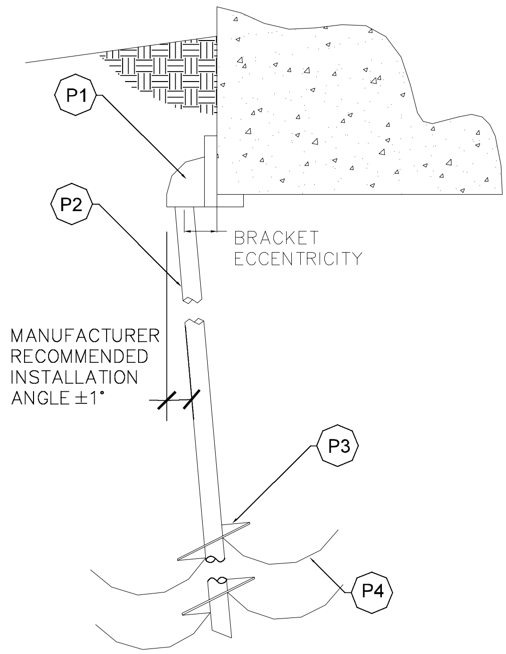


FIGURE 1—SIDE LOAD APPLICATION

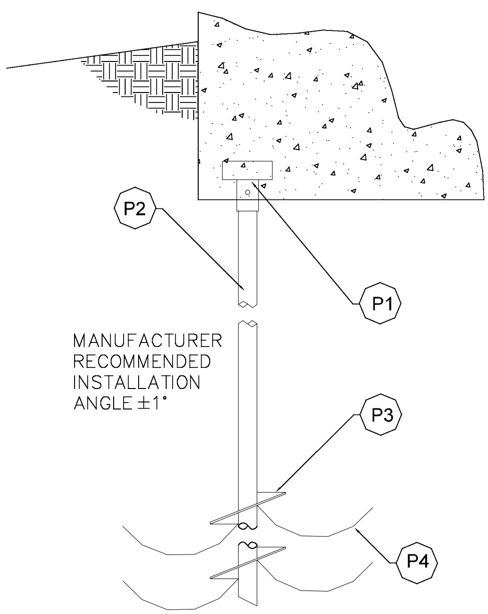


FIGURE 2—DIRECT LOAD APPLICATION

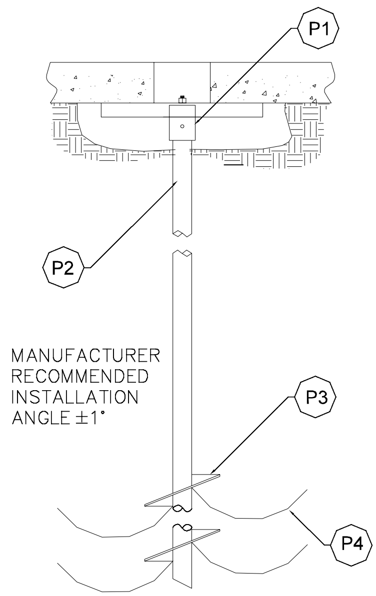


FIGURE 3—SLAB SUPPORT APPLICATION

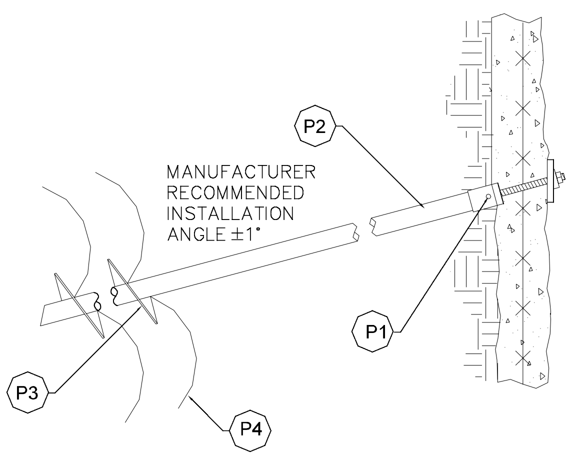


FIGURE 4—TENSION ANCHOR APPLICATION

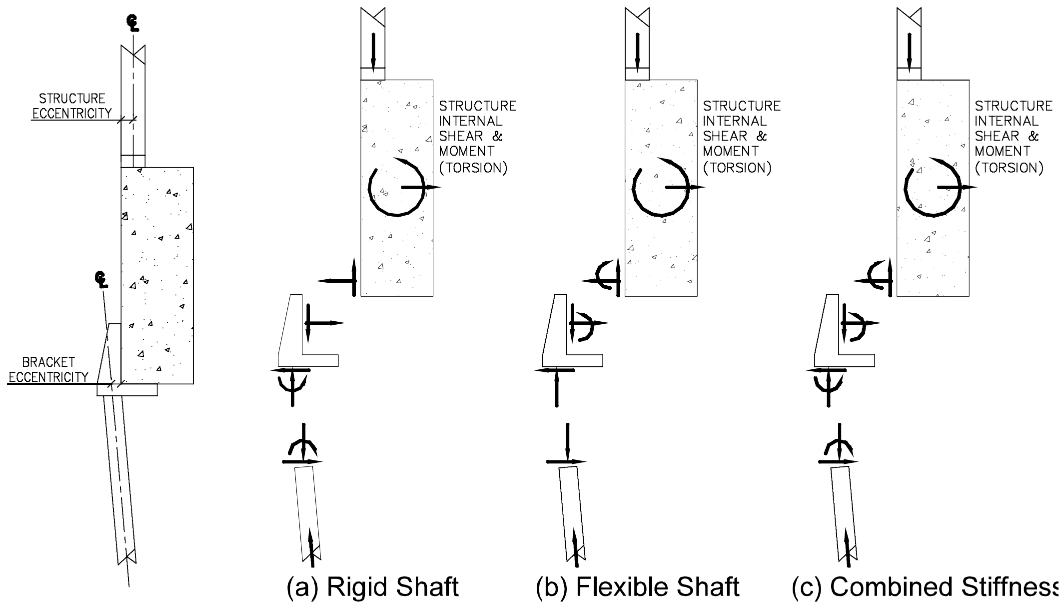


FIGURE 5—TYPE A BRACKET FREE BODY DIAGRAMS

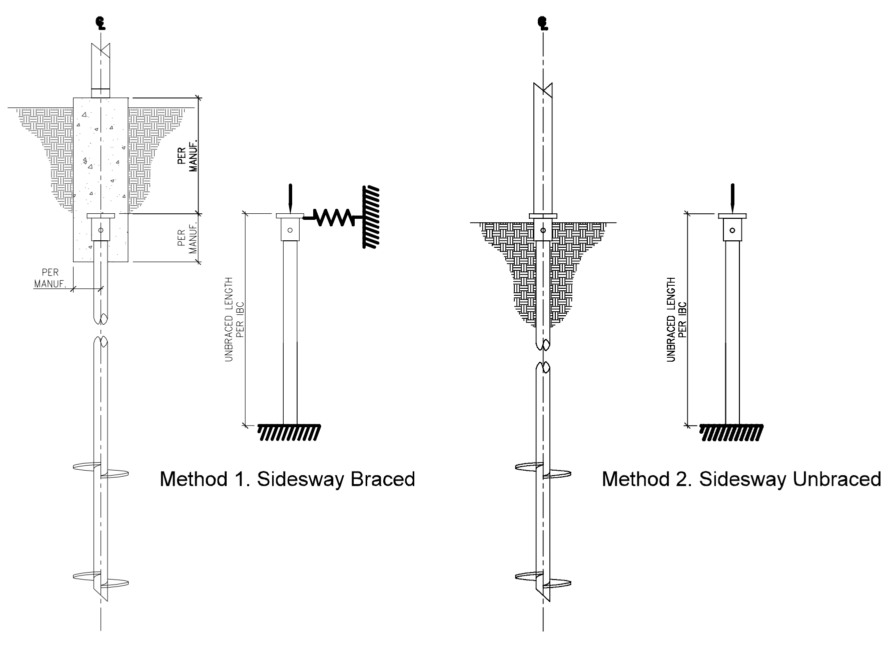
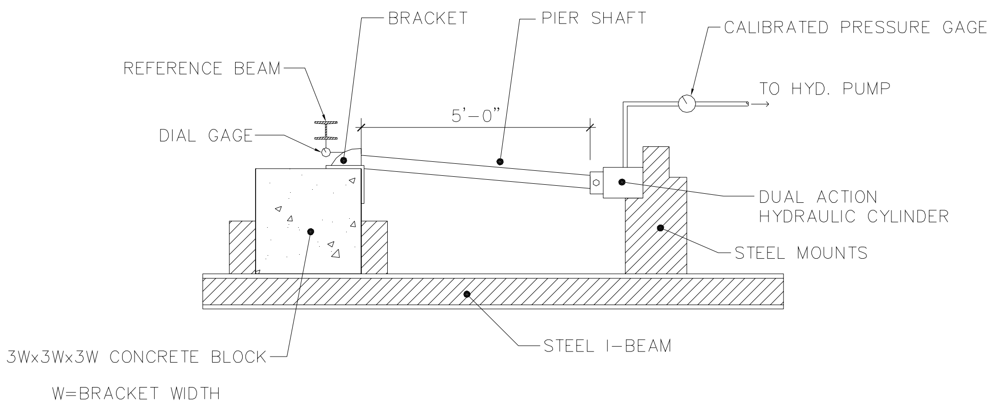
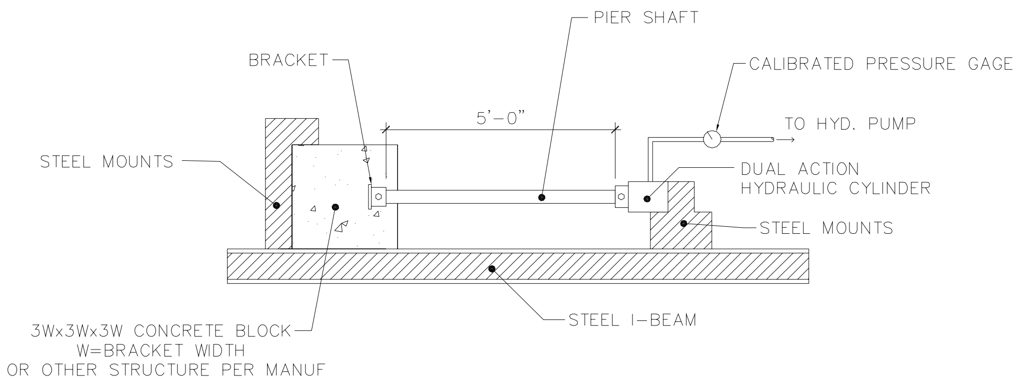


FIGURE 6—TYPE B BRACKET FREE BODY FORCE DIAGRAMS



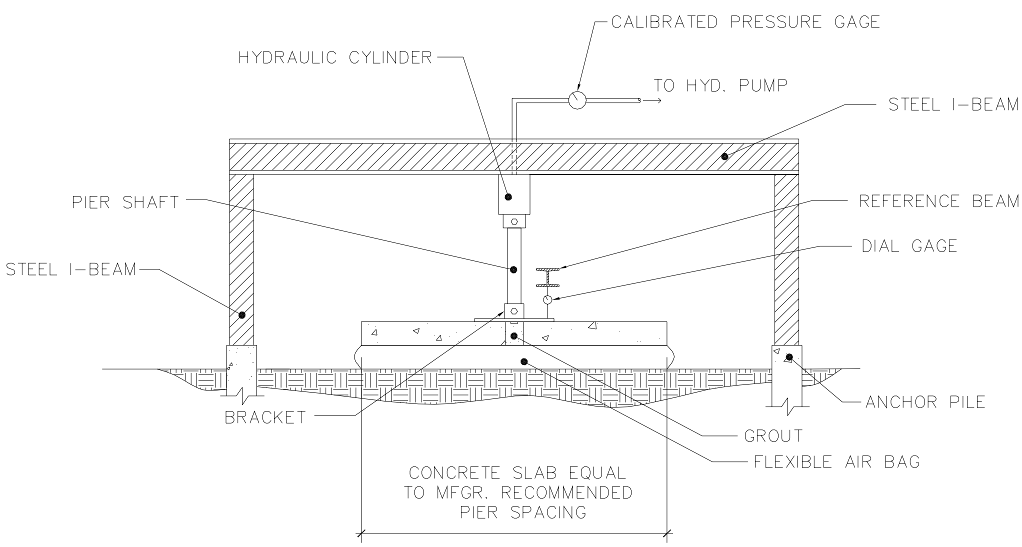
For **SI:** 1 inch = 25.4 mm.

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



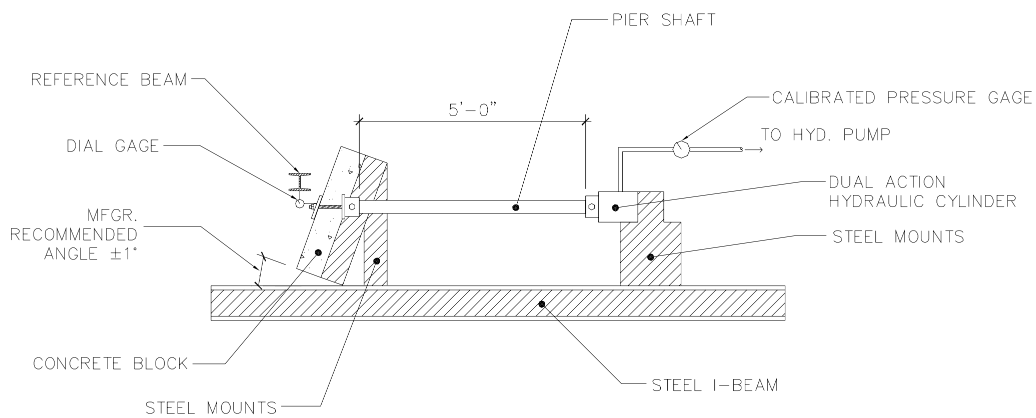
For **SI:** 1 inch = 25.4 mm.

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



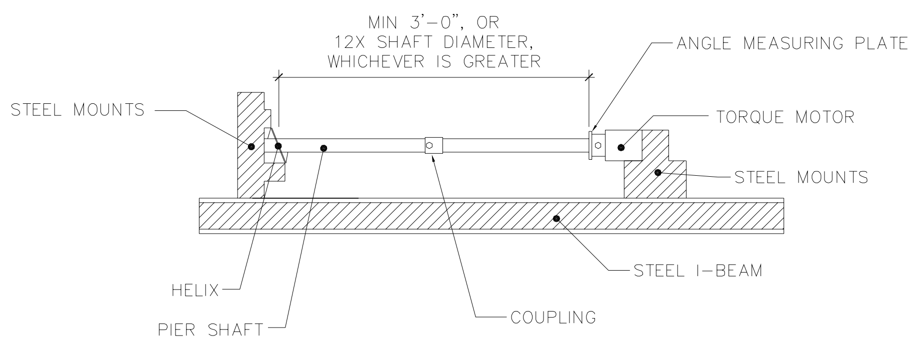
For **SI:** 1 inch = 25.4 mm.

FIGURE 9—TYPE C BRACKET EXAMPLE LABORATORY TEST SET-UP



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

FIGURE 10—TYPE D BRACKET EXAMPLE TEST SET-UP



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

FIGURE 11—SHAFT TORSION EXAMPLE LABORATORY TEST SET-UP

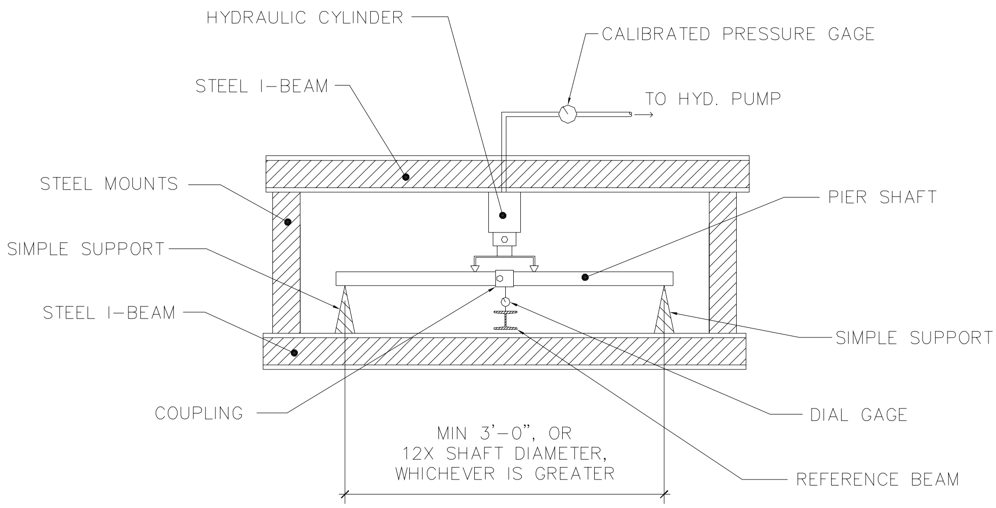


FIGURE 12—SHAFT BENDING EXAMPLE LABORATORY TEST SET-UP

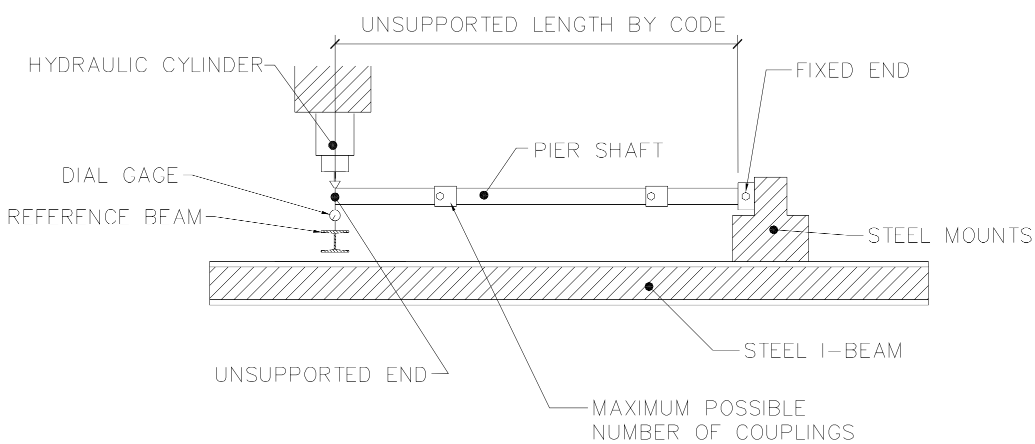


FIGURE 13—COUPLING RIGIDITY EXAMPLE LABORATORY TEST SET-UP

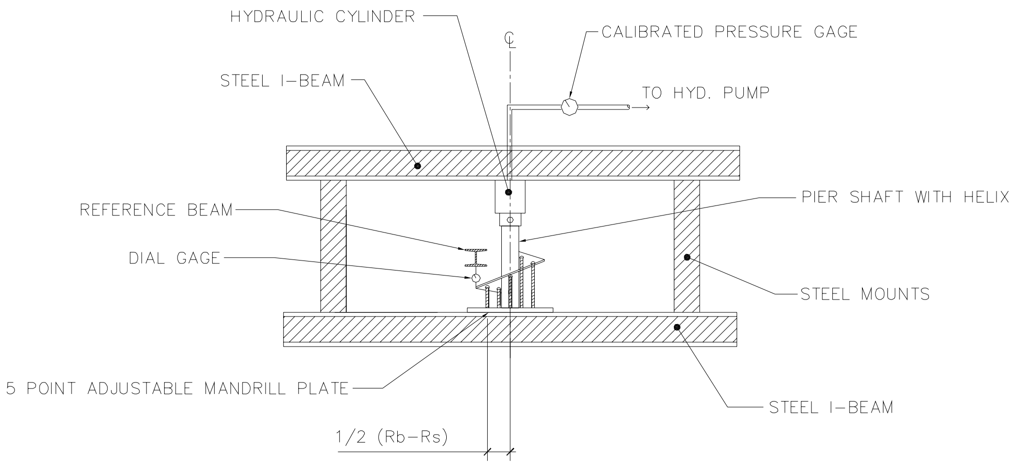


FIGURE 14—HELIX EXAMPLE LABORATORY TEST SET-UP