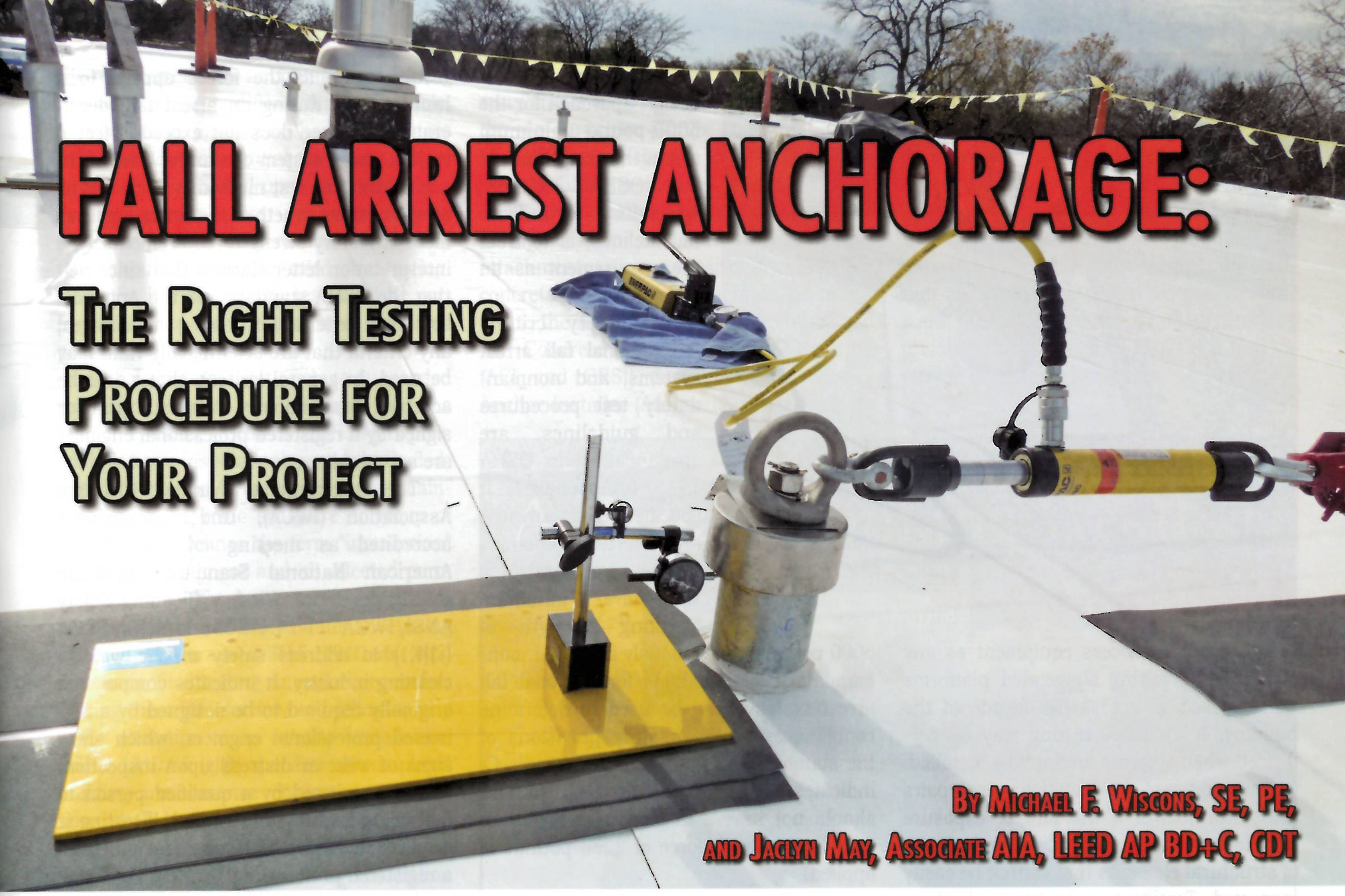

FALL ARREST ANCHORAGE:

The Right Testing Procedure for Your Project

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INTRODUCTION

When it is time to inspect or perform maintenance on mid- or high-rise building façades, suspended scaffolding is often the preferred method of access. In addition to proper rigging, attaching fall arrest to sturdy anchorage is essential. As such, fall arrest anchorage should be evaluated when systems are initially installed, when significant modifications or repairs are performed, or if use and/or exposure have led to concerns regarding the integrity of structural elements that cannot be easily inspected. Since each project is unique, it is important that the engineer responsible for evaluating fall arrest anchorage understands how to implement proper testing procedures. This article provides a brief review of standards related to fall arrest anchor testing, describes testing procedures for a specific fall arrest anchorage installation project, and includes a discussion of reference standards, testing forces, testing equipment, and results analysis.

DEFINITIONS

A fall arrest system is defined in ANSI/ASSE Z359.0 as the collection of equipment components that are configured to arrest a free fall. It is typically comprised of components such as full-body harnesses, lanyards, deceleration devices, horizontal or vertical lifelines, anchorages, and anchorage connectors. Anchorage is defined in ANSI/ASSE Z359.0 as a secure connecting point or a terminating component of a fall protection system or rescue system capable of safely supporting the impact forces applied by a fall protection system or anchorage subsystem.

The standard distinguishes between an anchorage and an anchorage connector. An anchorage is typically a fixed structural member such as a post, stanchion, or beam; an anchorage connector is a component that provides an interface to which the fall protection or rescue system may be attached when the anchorage does not have a compatible connection point, such as a strap or choker.

APPLICABLE STANDARDS AND TESTING FORCES

ANSI/ASSE Z359.2 and OSHA 1910.66, Appendix C, indicate anchorages selected for fall arrest systems shall have strength capable of sustaining static loads of at least 5000 pounds for noncertified anchorages, or two times the maximum force to stop a fall (arresting force) for certified anchorages. Certified anchorages are designed, selected, and installed by a qualified person. When more than one fall arrest system is attached to the anchorage, the aforementioned strengths shall be multiplied by the number of systems attached to the anchorage. The Occupational Safety and Health Administration (OSHA) does not provide mandatory requirements regarding load testing of anchorages. However, nonmandatory testing could be performed to verify anchorages comply with the strength requirements.

In 2015, the American Society of Civil Engineers (ASCE) published *Façade Access Equipment – Structural Design, Evaluation, and Testing* (*ASCE Façade Access Equipment*). It was developed by the Architectural Engineering Institute (AEI) Task Committee on Façade Access Design Guidelines to help engineers better understand the structural engineering requirements that govern the design, evaluation, and testing of permanent building-supported façade access equipment. The document

Figure 1 – Proprietary stanchion with a top eyebolt attached to concrete roof deck with adhesive anchors.

refers to façade access equipment as any equipment involving suspended platforms that is used to access the façade of the building. It indicates testing may be performed when systems are initially installed, when significant modifications or repairs are performed, or if use and/or exposure have led to concerns regarding the integrity of structural elements that cannot be easily inspected. Testing may be required when, in the judgment of the engineer responsible for the evaluation, it is necessary to confirm that the system conforms to the minimum OSHA strength requirements. ASCE Façade Access Equipment also clarifies that a rational design approach for the 5000-pound minimum strength requirement per OSHA 1910.66, Appendix C for individual lifelines, is to treat the requirement as an ultimate load.

Mandatory criteria for personal fall arrest systems, and nonmandatory test procedures and guidelines, are also included in OSHA 1910.66, Appendix C. It specifies that lanyards and vertical lifelines that tie-off one employee shall have a minimum breaking strength of 5000 pounds. As previously indicated, nonmandatory test methods for personal fall arrest systems may be used to determine compliance with mandatory provisions of the standard. OSHA 1910.66, Appendix C, indicates anchorage should be rigid and should not have a deflection greater than 0.04 inch when a force of 2250 pounds is applied.

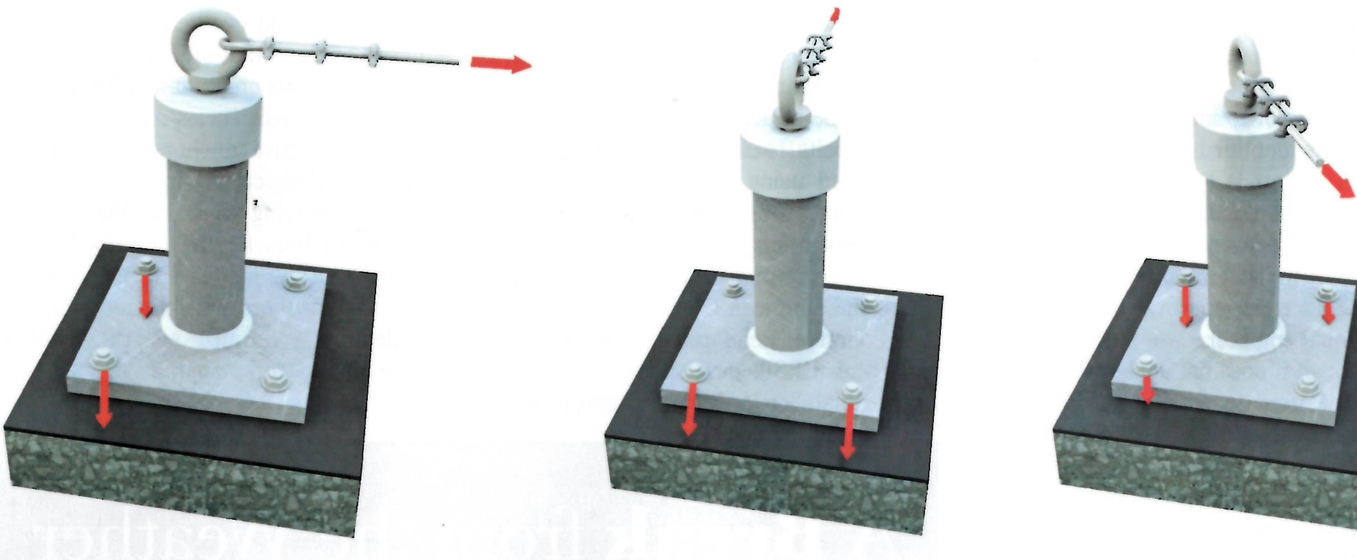
According to an interpretation letter from OSHA dated August 10, 2000, nonmandatory test methods are designed for a laboratory setting. Nonmandatory test methods are to ensure anchorages will not affect personal fall arrest system test results, such as the forces applied to a human body during an arrest fall, deceleration distance does not exceed 3 feet 6 inches, and a system can arrest a fall without failure. The test method is not a means of establishing whether the anchorage has met mandatory strength requirements. The interpretation letter clarifies that since neither the OSHA standard nor the Appendix sets test criteria for testing anchorages, any criteria that are scientifically valid may be used. In general, criteria that would be accepted by an industry consensus group or signed by a registered professional engineer are acceptable.

The International Window Cleaning Association (IWCA), under procedures accredited as meeting criteria by the American National Standards Institute (ANSI), developed Window Cleaning Safety ANSI/IWCA I-14.1-2001 (ANSI/IWCA I-14.1) to address safety in the window cleaning industry. It indicates components originally required to be designed by a registered professional engineer, which show signs of wear or distress upon inspection, shall be reviewed by a qualified person to determine if testing is required. If testing is deemed necessary, the document indicates a registered professional engineer shall prescribe a test procedure and certify its results. It also indicates anchorages shall be certified before initial use by window cleaners, inspected annually by a qualified person, and recertified when reroofing or at periods not to exceed ten years. Although the requirements for anchorage field-testing needed to obtain certification are debatable, it is standard practice to have anchorages field-tested prior to initial use. If an area of suspicion is identified upon inspection by a qualified person, a test procedure may be necessary. The document does not specify who should determine need for testing. However, it indicates the test shall be performed under the approval of a registered professional engineer.

Although it does not apply to suspended scaffolding used to service buildings on a temporary basis, OSHA 1910.66 covers powered platform installations permanently dedicated to interior or exterior building maintenance of a specific structure or group of structures. It defines the term "installation" as all the equipment and all affected parts of a building that are associated with the performance of building maintenance using powered platforms. OSHA 1910.66 (c)(2) discusses field-testing installations before placing them into service, and following any major alteration to an existing installation. OSHA 1910.66 (g)(1) specifies all completed building maintenance equipment installations shall be inspected and tested in the field before being placed in initial service to determine that all parts of the installation conform to applicable requirements of the standard, and that all safety and operating equipment is functioning as required. ASCE Façade Access Equipment indicates that although not required for equipment that supports only construction activities, inspection and testing are prudent and recommended for all equipment, whether used for maintenance or construction.

ASCE Façade Access Equipment indicates that when performing testing, the direction of test loads is generally the same as that expected for in-service loads. Test loads are usually applied relatively quickly, over the course of one to two minutes. The document also suggests loading the component or system being tested twice or preloaded, since test loads typically exceed sustained loads. As such, some unrecoverable movement, due to slippage, should be expected. The initial loading should be performed slowly to permit observation of instability, should it occur. Excessive rotation or lateral displacement of anchorages may be a sign of instability. Upon completion of full-load application, the loading should be removed and reapplied while deflections are monitored.

Anchorage for fall arrest systems on concrete roofs often consists of a proprietary stanchion with top eyebolt attached to the roof structure (*Figure 1*). These assemblies can be attached to the structure with through-bolts, welded to structural steel, or attached using adhesive or other types of anchors. In the authors' experience, attachment using adhesive anchors into concrete structures is common. In recent years, the American Concrete Institute and the Concrete Reinforcing Steel Institute (ACI and CRSI) developed an Adhesive Anchor Installer (AAI) certification program for horizontal and overhead installation of adhesive anchors that are subjected to sustained loads. This program was developed to address many deficiencies related to installation of adhesive anchors into concrete substrates that could drastically reduce their load-carrying capacity. Although the adhesive anchors for the described condition are typically installed vertically downward, the authors recommend they be installed by a certified ACI/CRSI AAI to ensure quality workmanship.



Figures 2A, 2B, and 2C – Multiple loading directions create maximum tension in different anchors.

PRE-TEST PLANNING

As described in ASCE Façade Access Equipment, prior to implementing structural load testing, the engineer responsible for testing should develop a plan outlining test procedures and equipment, application of loads, and acceptance/failure criteria. This should include consideration of suitable reaction points and necessary testing equipment. Reaction points should be evaluated by a qualified person, as some building components may not have sufficient strength for testing fall arrest anchorages. When multiple roof anchorages are available, they may be used to provide resistance for testing each other. Prior to testing, access to and configuration of the fall arrest anchorage should be considered. Collectively, testing equipment is often heavy, and proper planning is necessary to bring the equipment to the testing location. Distances between reaction points should be evaluated prior to testing, in order to supply equipment with sufficient length to span between desired reaction points. Depending on existing conditions and the direction of tests, obstructions between reaction points may also need to be evaluated. This may require coordination with the building owner or a contractor to relocate obstructions.

Figure 3 – Vapor retarder removal for fall arrest anchorage directly to concrete roof deck.

It is important to test fall arrest anchorage in directions in which it could possibly be used during service. Since each anchorage could be used in various configurations that would subject it to load from multiple directions, several tests on a single anchorage may be necessary to replicate potential anchor tension of in-use conditions. Due to existing conditions, some fall arrest anchorages may be difficult to test in multiple directions. Testing could entail hanging weights over the side of a building in order to simulate actual loading. Alternatively, applying loads in multiple directions to anchorages will develop maximum tension in different anchors (*Figures 2A, 2B,* and *2C*). Applying loads in opposite directions may be required to test each anchor's maximum tension.

In the authors' opinions, predicting how each anchor will be used in the future and testing it in all foreseeable directions is not practical. Consequently, a method should be developed to ensure anchors are tested in various configurations that replicate maximum load combinations on each anchor used to attach the anchorage to the structure.

Figure 4 – Testing equipment for fall arrest anchorage.

Figure 5 – Hydraulic hand pump and pressure gauge.

FIELD TESTING CASE STUDY

A recent field testing case study of 31 fall arrest anchorages is presented to illustrate the procedure and equipment used, as well as field conditions that affected test procedures and results. The fall arrest anchorages tested consisted of newly installed proprietary stanchions with a top eyebolt, attached to a concrete roof deck with adhesive anchors installed during a full roof tear-off and replacement project. Project specifications required that an ACI/CRSI AAI install and perform testing on adhesive anchors at each stanchion. The testing performed by the ACI/CRSI AAI was limited to testing the pullout resistance of each adhesive anchor, and did not test the load capacity of the anchorage assembly.

For this project, anchorages were installed over two different substrates. Some anchorages were installed directly on the roof deck (*Figure 3*). Others were installed on top of 120-mil-thick vapor retarder membrane over the roof deck.

Planning

Prior to testing, the fall arrest anchorage layout was evaluated to consider reaction points, anchorages, reaction point access, distances between anchorages and reaction points, and directions in which anchorages may be tested. For this project, fall arrest anchorages were tested in multiple directions by reacting against adjacent anchorages, due to field conditions and lack of suitable existing reaction points.

Equipment

To perform the test, aircraft cable attached to a cable winch puller and a single-acting hydraulic pull cylinder with eyebolt connections on both ends was connected to top eyebolts between two adjacent anchorages (*Figure 4*). The cable winch puller was used to reduce initial slack in the aircraft cable. A hydraulic hand pump capable of a maximum pressure of 10,000 pounds per square inch (psi) and pressure gauge were attached to a pull cylinder to provide the desired tension between the two anchorages by compressing the pull cylinder (*Figure 5*). The single-acting pull cylinder had a capacity of five tons. A pump hose attaching the hydraulic pump to the pull cylinder was of sufficient length to allow testing personnel to locate themselves several feet away from anchorages being tested, for safety. A dial deflection gauge with gradations of 0.001 inch was used to measure deflection (*Figure 6*). Dial deflection gauges with small gradations are preferable because they are easier to read accurately from a safe distance compared to gauges with larger gradations. The dial deflection gauge was attached to a magnetic base and adjustable stand (*Figure 7*). A small steel base plate was used to provide a magnetic and level surface for the gauge-stand to rest. The dial gauge indicator point was positioned to measure deflection at the highest possible point on the anchorage post. Protection was provided beneath the cable winch puller, pull cylinder, steel plate, and hydraulic hand pump to avoid damaging the new roofing system.

It should be noted that most guidelines refer to recommended testing forces in pounds. However, testing equipment typically provides pressure measurements in pounds per square inch (psi). As such, testing personnel converted tension forces to pressure measurements, based on the effective area of the pull cylinder used, prior to performing tests. Alternatively, a load cell

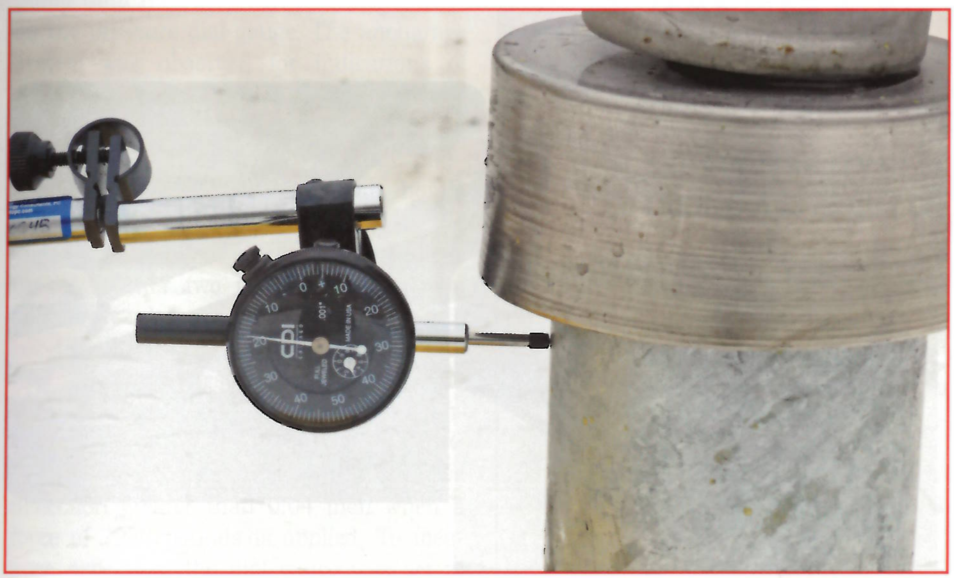


Figure 6 – Dial deflection gauge with gradations of 0.001 inch.

can be used to provide direct measurements of the force.

Safety

Prior to commencing each test, testing personnel positioned themselves perpendicular to the direction of testing and several feet away, for safety. If fall arrest anchorages pull out of the substrate upon testing, the aircraft cable or other equipment might fail in line with the two reaction points and cause injury. Testing personnel should wear personal protection gear, such as hard hats, safety glasses, and gloves. They should also ensure that others on site remain clear of the test area during the entire test duration.

Testing Procedure

The engineer responsible for the evaluation of the anchorage testing should determine the required full load, based on the working load of the anchorage. Maximum working load requirements for anchorages on this project were 1250 pounds. These loads were indicated on each anchorage point with permanent metal tags. As such, they were tested to resist a full load of 2500 pounds, which is two times the working load, in accordance with ASCE Façade Access Equipment recommendations of ANSI/ASSE Z359.2, and OSHA 1910.66 Appendix C strength requirements. The test load on the anchorage was imparted by slowly applying 2500 pounds of tension, which equated to 2250 psi of pressure in the hydraulic system. The reaction point for each test was a series of carefully selected anchor points as reaction points. Testing was done by applying the hydraulic hand pump until the full pressure was observed on the pressure dial gauge. The anchorage system was observed for indications of instability using a dial gauge. After 2500 pounds was achieved, tension was held for two minutes. Due to potential small pressure leaks in the hydraulic pump, hoses, valves, and pull cylinder, additional pumping was necessary to maintain the required pressure. After two minutes, the tension was slowly released.

After the full-load test was performed, the system was tested again. As a basis for testing, the engineer chose the nonmandatory OSHA 1910.66, Appendix C provision that anchorages should not have deflection greater than 0.04 inch when a force of 2250 pounds is applied. To measure deflection, the dial gauge was set to zero prior to loading. After 2250 pounds of tension was applied to the anchorage, tension was held for five minutes, and testing personnel observed and recorded anchorage deflection.

After five minutes, some anchorage deflections exceeded 0.04 inch. This prompted further investigation. Structural analysis of the anchorages was performed, which indicated calculated deflections were less than 0.04 inch. As such, additional testing of anchorages having excessive deflection was performed. For those conditions, a larger test load was applied in order to check the anchorage capacity. A load of 4000 pounds was chosen by the engineer to approach the ultimate load without exceeding it or the adhesive anchor yield stress. Testing beyond anchor yield stress causes permanent deformation of anchors and may render them unusable. After the 4000-pound load was achieved, tension was maintained for five minutes. During this retesting, the testing personnel observed that the deflection remained constant from the time the

Figure 7 – Dial deflection gauge attached to adjustable stand and magnetic base fastened to a steel plate.

load was applied. Noting that some anchorages were installed over 120-mil-thick vapor retarder membrane, while other anchorages were installed directly on the concrete roof deck, the initial large deflections observed were determined to be due to crushing of the membrane under the anchorages. It was concluded that the large deflections were not due to deficiencies of the fall arrest anchorages because deflections remained constant after load application and under increased tension forces. Since restricting anchorage deflections to 0.04 inch is not mandatory and they had sufficient strength, it was the authors' opinion that the fall arrest anchorages were acceptable. As such, no modifications to the installed anchorages were needed.

SUMMARY

Applicable standards and guidelines should be reviewed prior to field-testing roof fall arrest anchorages. ANSI/ASSE Z359.0, ANSI/ASSE Z359.2, *ASCE Façade Access Equipment* guidelines, OSHA 1910.66, OSHA 1910.66's Appendix C, and ANSI/IWCA I-14.1 are pertinent reference documents related to the subject. In some cases, the maximum nonmandatory deflection criteria indicated by OSHA 1910.66, Appendix C, may not be achieved due to existing field conditions, such as crushing of a membrane between the anchorage base plate and the substrate.

The procedures described in the case study were the authors' interpretation of the appropriate process and equipment needed to provide field-testing of roof fall arrest anchorage for the particular condition described. Since each project provides its own set of challenges, proper planning and procedures are important to effectively test fall arrest anchorage and to evaluate the results.

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Architectural Firms' Phone Manners Need Work, Customers Say

Only 20% of customers of architectural firm customers are happy with the companies' call-handling standards – the lowest percentage among the industry groups listed in a survey.

British audio branding specialist PH Media Group surveyed 2,234 people in 2015 – the largest study of its kind conducted in America. Their results showed the average standard of customer happiness over the handling of phone calls across all industries was 32%, with the insurance industry performing best, at 41%.

"Poor call handling is a frustrating experience for the American consumer and can be the difference between attracting new business and putting potential clients off permanently," said Mark Williamson, CEO at PH Media Group.

The study also discovered that people in the South and the Northeast are more satisfied, and 45- to 64-year-olds are the least satisfied. Women are more patient than men, and people become more patient with age.

— PH Media Group and other sources