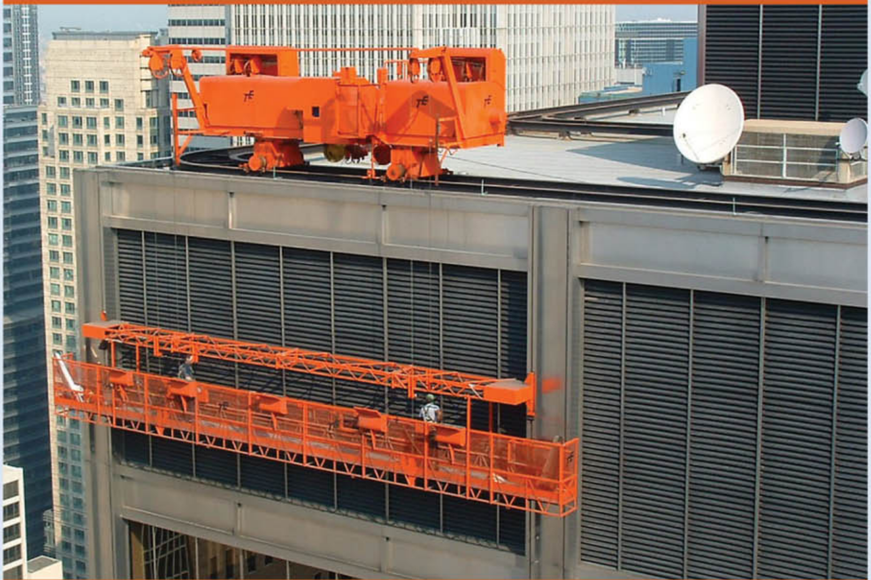

Façade Access Equipment

STRUCTURAL DESIGN, EVALUATION, AND TESTING

Task Committee on
Façade Access Design Guidelines

ASCE
AEI ARCHITECTURAL ENGINEERING INSTITUTE

Façade Access Equipment

Structural Design, Evaluation, and Testing

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Sponsored by
Committee on Seismic Effects on Nonstructural Components of the
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Preface

This document was developed by the Architectural Engineering Institute (AEI) Task Committee on Façade Access Design Guidelines. The purpose of this document is to provide guidance to structural engineers, architects, building officials, and others in the architectural and engineering industries regarding the design, evaluation, and testing of permanently dedicated anchorages and components that support façade access equipment and fall-arrest systems.

This guideline addresses the structural engineering requirements applicable to permanent building-supported façade access equipment contained in the United States *Code of Federal Regulations* (CFR), as promulgated by the Federal Occupational Safety and Health Administration (OSHA), as of July 1, 2014. Local building jurisdictions as well as state occupational safety and health administrations may have additional requirements that are not discussed in this document. For each specific project, applicable local and state requirements should be confirmed.

The suggestions, recommendations, and commentary discussed in this document are offered in an advisory capacity only. This document is not intended to serve as a building code.

The guideline is divided into two sections: the guidelines and related commentary.

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Introduction

OVERVIEW OF OSHA REQUIREMENTS

OSHA has numerous requirements that govern the design, use, evaluation, and testing of façade access equipment. These requirements are part of the CFR. OSHA standards that govern façade access equipment are found in various sections in 29 CFR. Specifically, 29 CFR §1910 covers General Industry requirements (i.e., building maintenance), while 29 CFR §1926 covers Construction Industry requirements. Although the relevant structural requirements for façade access equipment are contained within 29 CFR §1910 and 29 CFR §1926, the requirements are interspersed with thousands of other requirements that are not related to structural engineering. In addition, the provisions that *are* related to structural engineering are often less than clear in terms of their intent due to OSHA's use of terminology that is not common in the structural engineering profession. For this reason, AEI is publishing this guideline to help engineers better understand the structural engineering requirements that govern the design, evaluation, and testing of permanent building-supported façade access equipment.

Within this publication, the designation "29 CFR" will be commonly understood to precede all OSHA sections mentioned herein. All OSHA provisions quoted herein are current as of July 1, 2014.

OSHA standards are available online at **www.osha.gov**. In addition to these standards, OSHA publishes official responses to questions submitted in writing by the public (i.e., *Standard Interpretations*) that are considered important clarifications to the published standards.

OSHA Structural Design Requirements

The following discussion covers OSHA's basic structural design requirements for permanent building-supported façade access equipment. The discussion is not intended to be all-inclusive, but rather to provide insight concerning the structural design provisions that follow.

Platform Supports

Platforms, which may be powered or non-powered, and include both scaffolds and boatswain's chairs, are suspended work areas that can be raised (depending on type) and lowered along the face of a building. In all cases, OSHA requires platform/scaffold support elements to be able to support 4 to 4.5 times the maximum intended in-use load on the platform supports. Example provisions include the following:

- §1910.28(a)(4): "Scaffolds and their components shall be capable of supporting without failure at least four times the maximum intended load."
- §1910.28(g)(2): "The hangers of two-point suspension scaffolds shall be made of wrought iron, mild steel, or other equivalent material having a cross-sectional area capable of sustaining four times the maximum intended load . . . "
- §1910.66(f)(3)(i): "The carriages and their anchorages shall be capable of resisting accidental over-tensioning of the wire ropes suspending the working platform, and this calculated value shall include the effect of 1.5 times the stall capacity of the hoist motor." And, "The motors shall stall if the load on the hoist motors is at any time in excess of three times that necessary for lifting the working platform with its rated load."

  Note: Since the maximum intended load is limited by the rated load of a hoist, and since the stall load of a hoist can be up to three times the rated load; it therefore follows that 1.5 times the stall capacity of the hoist may be up to 4.5 times the maximum intended load.
- §1910.66(f)(3)(ii): "Each transportable outrigger shall be secured with a tie-down to a verified anchorage on the building during the entire period of its use. The anchorage shall be designed to have a stability factor of not less than four against overturning or upsetting of the outrigger." And, "Each transportable outrigger shall be designed to support an ultimate load of not less than four times the rated load of the hoist."
- §1910.66(f)(3)(iii): "Every davit installation, fixed or transportable, rotatable or non-rotatable shall be designed and installed to insure that it has a stability factor against overturning of not less than four."
- §1926.451(d)(1): "All suspension scaffold support devices, such as outrigger beams, cornice hooks, parapet clamps, and similar devices, shall rest on surfaces capable of supporting at least 4 times the load imposed on them by the scaffold operating at the rated load of the hoist (or at least 1.5 times the load imposed on them by the scaffold at the stall capacity of the hoist, whichever is greater)."

  Note: As with §1910.66, stall capacity may be up to 3 times the rated hoist capacity. Therefore, 1.5 times the maximum permissible stall load corresponds to a minimum strength requirement of 4.5 times the rated hoist capacity.

OSHA load terminology is distinctly different from that used by most other structural engineering design standards. In order to provide the necessary strength, it is important to embrace a rational interpretation of OSHA terminology. Like most design standards, the OSHA provisions require the capacities of key structural components to be greater than the loads they are expected to sustain under rather severe service conditions. This approach reduces the risk of failure as it accommodates a certain amount of deviation from the assumed service conditions and material properties. To represent expected service conditions, OSHA typically uses the following terms:

- §1910.28: "Design working load. The maximum intended load, being the total of all loads including the weight of the men, materials, equipment, and platform."
- §1910.66: "Live load means the total static weight of workers, tools, parts and supplies that the equipment is designed to support."
- §1910.66: "Platform rated load means the combined weight of workers, tools, equipment and other material which is permitted to be carried by the working platform at the installation, as stated on the load rating plate."
- §1910.66: "Rated load means the manufacturer's recommended maximum load."
- §1910.66: "Rated working load means the combined static weight of men, materials, and suspended or supported equipment."
- §1926: "'Rated load' means the manufacturer's specified maximum load to be lifted by a hoist or to be applied to a scaffold or scaffold component."
- §1910 and §1926: "Maximum intended load" is synonymous with "rated load."

Although OSHA standards use a number of different terms to describe service load conditions, the above definitions clearly describe static, gravity-based loads considered acceptable under normal operating conditions. As such, they are equivalent to what most structural design standards call service or unfactored loads. As indicated previously, the elements that support these loads must have capacities significantly greater than the maximum intended load, typically by a factor of 4 or more. While this level of capacity might seem excessive compared to load factors commonly used in structural design, it is important to understand that suspended scaffold systems are actually machines. This is significant because, like many machines, a scaffold system can generate forces on its components that greatly exceed those associated with external demands such as gravity and wind. For example, a scaffold descending along the face of a building can temporarily hang up on a projecting element of the façade. When this happens, continued operation of the hoists can create slack in the suspension lines. If the scaffold were to break free of the obstruction and fall some distance, it would be stopped by the suspension lines resulting in dynamic impact forces on the system much greater than the static weight of the platform and its contents. Requiring the support elements to be able to carry several times the static weight of the loaded platform should preclude failure under most hang-up-and-fall scenarios.

Hoist overload represents another loading that, although not "normal" or "intended" should certainly be considered. Hoist overload occurs when upward movement of the platform is prevented by some form of obstruction such that continued operation of the hoist generates additional tension in the suspension lines exceeding the weight of the supported platform and its contents. Since the amount of force generated in the suspension lines under this circumstance depends on the capacity of the hoist, OSHA requires a hoist to stop operating or "stall" before it exceeds 3 times its rated capacity. Since hoists are allowed to generate forces up to 3 times their rated capacities, OSHA developed provisions specifically to address this possible loading condition. For systems designed according to §1926, or for carriage systems designed according to §1910.66, OSHA requires support elements to be able to sustain 1.5 times the stall load of the hoist, which provides a 1.5 factor of safety for the stall loading condition. If support elements were only designed for 4 times the rated capacity of the hoist (§1910.28 and §1910.66 - except for carriage systems), the support elements would provide a factor of safety of just 1.33 for a hoist stalling at 3 times rated load.

For structural design and evaluation purposes, the OSHA-specified minimum strength requirements for scaffold support elements should be treated as "ultimate" or "factored" loads, because they are considerably larger than the maximum expected operating (or service) loads.

Fall Arrest Anchorages

Fall arrest (lifeline) anchorages are designed to catch a worker who experiences a fall. Where specific provisions are provided (i.e., in §1926 and §1910.66), OSHA requires lifeline anchorages to conform to the following:

- §1910.66 Appendix C (c)(10): "Anchorages to which personal fall arrest equipment is attached shall be capable of supporting at least 5,000 pounds (22.2 kN) per employee attached, or shall be designed, installed, and used as part of a complete personal fall arrest system which maintains a safety factor of at least two, under the supervision of a qualified person."
- §1926(d)(15): "Anchorages used for attachment of personal fall arrest equipment shall be independent of any anchorage being used to support or suspend platforms and capable of supporting at least 5,000 pounds (22.2 kN) per employee attached, or shall be designed, installed, and used as follows:
    - §1926.502(d)(15)(i) as part of a complete personal fall arrest system which maintains a safety factor of at least two; and
    - §1926.502(d)(15)(ii) under the supervision of a qualified person."

The basic requirement is that fall arrest anchorages must have a capacity of at least 5,000 lbs per attached lifeline. Although sections §1910.66 Appendix C(d)(1)(ii) and §1926.502(d)(16)(ii) require that the fall arrest force be limited to 1,800 lbs, OSHA explicitly allows larger forces. Both §1910.66 and §1926 permit the use of fall arrest systems that exert up to 2,520 lbs of restraining force when tested under conditions meant to replicate permissible fall situations. Given this allowance, the basic OSHA "safety factor" regarding lifeline anchorage capacities is approximately equal to 2, which is consistent with the provisions related to custom designed systems that must be used under the supervision of a qualified person. Maximum arresting forces are dependent on numerous factors, including the weight of the person, the fall distance, and the stopping distance. As a result, the theoretical maximum arresting force, whether 1,800 or 2,520 lbs, may be exceeded depending on actual in-field conditions; hence OSHA's requirement for a design load of 5,000 lbs per attached lifeline. Given the above, a rational design approach would be to treat the 5,000-lb minimum strength requirement as an ultimate or factored load although OSHA does not explicitly state that this is the case.

OSHA also provides interpretation letters and memos that are intended to clarify OSHA's requirements; however, these letters and memos sometimes create more confusion, as discussed in a later section.

OSHA Load Testing and Certification Requirements

OSHA requires that building owners provide assurance to users of building maintenance (façade access) equipment that the equipment (including the anchorages) meets all OSHA requirements. The assurance, or "certification" is required after initial installation of the equipment prior to its first use. If all components of the system's installation are visibly verified (i.e., steel components where all bolted or welded connections are verified prior to installation of roofing and other finishes that may hide connections) and are analyzed by a qualified person, then analysis may be an efficient way to achieve initial certification. However, if component connections are hidden, or if anchorages are embedded in concrete, then it may be necessary to test the equipment to achieve initial certification. OSHA does not provide specific requirements regarding load testing of façade access equipment and anchorages. Testing or other equivalent methods of certification are only required and are generally only performed when the 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 certain structural elements that cannot be easily inspected (e.g., connections that are buried within the roofing system). Occasionally, an owner will test an existing system if documentation of the initial testing is no longer available or if the initial testing was not performed. OSHA also requires that equipment be visually inspected by a competent person prior to each use; however, the visual inspection is not a substitute for a certification of a structural element's capacity.

Building owners seeking certification of their façade access systems typically rely on engineers to provide the required certification. By certifying equipment, the certifier is essentially verifying to the building owner that the equipment being used complies with *all* OSHA structural requirements. Since portions of the system are often obscured by roofing and other architectural elements, load testing is often the most economical and sometimes the only practical way to provide this verification. Load testing must be performed carefully and appropriately. The goal of load testing is to verify that the equipment actually has the minimum required structural capacity. Efforts should be made to ensure that the equipment and surrounding structure are not damaged by the testing. In some cases, particularly where the equipment was designed to undergo significant deformation and/or yielding and strain hardening to achieve the minimum required capacity, load testing may not be an appropriate means of verifying the minimum required capacity. In such cases, a more intrusive approach such as exposure, inspection, and analysis will be necessary - often in conjunction with limited load testing. This is one reason why designs should avoid relying on significant inelastic deformation whenever possible. The economic benefit of permitting non-intrusive load tests for verification more than offsets the small cost increase from using the next larger structural shape, plate, or anchor bolt to ensure elastic behavior under factored loadings.

OVERVIEW OF STRUCTURAL LOAD TESTING

For load testing to be useful, it must achieve the desired goal of verifying adequate strength of the element or elements being tested. If a test does not verify the equipment's ability to support the minimum required load, then the test is an inadequate basis for certifying that the equipment satisfies OSHA's structural requirements.

The possibility of causing damage must be considered when contemplating load testing. If testing to the required minimum loads cannot be done without causing significant damage to the test subject or the surrounding structure, other means of evaluating capacity should be employed. However, such situations should be rather rare. In general, load testing outcomes fall into one of three categories:

1. Required capacity is achieved and there is no damage (or there is inconsequential damage) to the tested element;
2. Required capacity is achieved but resultant damage practically precludes further use; or
3. Element fails during test and does not achieve required capacity.

In the first outcome, testing to the required full factored load proves the requisite capacity of the component. As a result, its compliance with applicable regulations can be certified and, more importantly, it can be used with confidence. In the third outcome, an attempt to test to the required load that leads to failure of the element proves that the element was deficient and appropriately prevents it from being used. The second outcome presents the relatively rare instance where an element can develop the minimum required strength, but only after sustaining sufficient inelastic deformation to render it unfit for future use without repair or replacement. The second outcome violates the recommendation of these guidelines that façade access elements be designed to remain elastic or nearly elastic under the full factored load.

The professional engineer in responsible charge of the testing should weigh the use of load testing against the probability of damage occurring. If an installation appears capable of providing the minimum required strength but only by sustaining significant inelastic deformation, then proof load testing is not a practical way to verify adequacy. Testing to a lesser load, to avoid causing damage, fails to achieve the required goal of verifying the minimum OSHA-specified capacity, which means it cannot be used as a basis for certifying OSHA compliance. In such cases, means other than load testing alone would be required.

Most load test outcomes fall into the first category even when testing imposes the full factored load on the element. This is due to well-established design practices that incorporate intentional conservatism in the design of structural elements, increasing the probability that those elements have the necessary minimum capacities. In other words, the *probable* strength of an element made of common structural materials is usually significantly greater than its *nominal* strength. As a result, most structural elements that are required to resist the full factored loads, including davits, davit bases, and lifeline anchorages, can do so without being damaged.

Some industry practitioners advocate testing façade access components to only 50 percent of the minimum required capacity. Some engineers have followed these recommendations and certified OSHA compliance based on testing that only proves the test subject is at least half as strong as it needs to be. One goal of this guideline is educating practitioners within the façade access industry of the potential dangers and inadequacies of certifying compliance of façade access components based on inappropriate tests such as load testing to only 50 percent of the minimum required capacity.

Many façade access elements subject to evaluation by testing have been in service for some time. Therefore, it is quite possible that some elements being tested have already been loaded to levels near and perhaps even beyond the minimum required strength. For example, a stage may have hung-up while ascending, resulting in a davit experiencing the stall load of its hoist; a davit may have been subjected to impact by a platform that hung up on a ledge and then fell several feet; and a davit base may have been loaded or struck by an HVAC contractor's crane. Because the evaluators of such elements cannot possibly be aware of their complete load histories - which may have included severe loads - one goal of testing is to determine whether any of the elements have been damaged to the extent that they can no longer sustain the minimum required loads.

It also may not be possible to visually assess the significance of damage that might be observed during an inspection. Load testing offers engineers the ability to directly assess whether the capacity of a component has been compromised. However, load testing to only half of the required minimum capacity is unlikely to identify whether damage has reduced the capacity unless that reduction is more than 50 percent of the original capacity. For example, suppose a davit originally had a capacity to support 4,000 pounds, but over the years, damage and/or corrosion has reduced its capacity such that the davit will fail in a brittle and sudden manner at 2,500 pounds. Load-testing the davit to only 2,000 pounds would fail to identify the problem. In fact, a 50 percent load test would be so low that, in this example, it would not even be sufficient to check against the stall load of the hoist.

As an example of how other codes and standards view load testing, one can refer to the current edition of ACI 318, *Building Code Requirements for Structural Concrete*. Chapter 20 includes requirements for load testing to evaluate the existing strength of concrete structures. Where the design load factors are 1.2 for dead load and 1.6 for live load, ACI requires load testing to a minimum of 1.15 times dead load and 1.5 times live load - or approximately equivalent to a minimum of 95 percent of the factored design load. In addition, ACI contains strict requirements regarding what constitutes a passing test, including limits on deflection and cracking during the test and requiring near-elastic recovery after testing. Similarly, the latest edition of the American Institute of Steel Construction's *Specifications for Structural Steel Buildings* requires load tests that are to be used as a basis for a structural load rating to include application of 100 percent of the factored loads. Thus, wherever façade access equipment is composed of steel or is connected to or supported by concrete or steel elements (i.e., nearly every building), these standards require the test load to be essentially 100 percent of the factored loads.

When load testing is the method used to evaluate installations, one question that arises fairly regularly is whether all installations need to be tested in order to certify the installations or whether it might be rational to load test only some fraction of the installations (e.g., only test the lifeline anchorages that are easily accessible) and extrapolate the results to the installations that were not tested. Since it is not possible to tell which installations may have a manufacturing or installation defect, which installations may have been damaged via an overload condition, or which installations may have been subject to hidden deterioration such as corrosion, it is generally not rational to limit load testing to just a limited number of the installations, particularly if the load testing is limited to 100 percent of the factored loads providing no data on the mean ultimate capacity or standard deviation of the population.

OSHA itself has contributed to some of the uncertainty regarding load testing within the façade access community. In a September 23, 1993 interpretation letter, OSHA stated that load testing is "predicated on the [125 percent] limitation of the hoist" and that a test to four times the rated load "could be characterized as destructive." This flawed interpretation has caused some people to insist that load tests should not exceed 125 percent of the rated load of the hoist and has caused others to insist that load tests to the full factored design load are destructive. Neither of these interpretations is correct. Although OSHA limits the load that can be applied to the hoist (i.e., motor) itself to 125 percent of its rated load, this simply means that the hoist cannot be used to apply test loads to the structural elements; test loads are commonly applied by other means, as described in later sections. Similarly, a load test is only destructive if it causes damage; one cannot assume that load tests to any particular value are destructive. If the design recommendations contained in this guideline are followed, load tests to the full factored design loads should typically not cause damage unless an installation was improperly designed or constructed or has sustained damage or deterioration that has compromised its ability to resist the required loads – in which case, load testing will identify the problems with the installation.

COMMON TYPES OF FAÇADE ACCESS EQUIPMENT

The following figures show various types of façade access equipment that are addressed in this guideline. Figure 1 shows two davits used to support a powered platform. Figure 2 shows a pair of transportable outriggers used to support a contractor-supplied powered platform. Figure 3 shows a parapet clamp with an outrigger arm. Figure 4 shows a rooftop carriage supporting a dedicated house rig. Figure 5 shows a pedestal-type lifeline or tieback anchorage, and Figure 6 shows a typical wall-mounted lifeline anchorage. Figure 7 shows a horizontal lifeline. Figures 8 through 14 show a number of different test setups that have been used to verify compliance with minimum load requirements.

Figure 1. Davit bases (white arrows) and davit arms (black arrows) being used to suspend a platform over the side of a building. Note that the connections of the davit bases to the primary building structure are often hidden from view and cannot be visually inspected without removal of roofing materials. Dotted white arrows indicate the hoists (motors).

Figure 2. Portable, contractor-supplied outrigger. Note the tieback cable (black arrow) at the interior end of the outrigger (dashed black arrow). In this case, the outrigger is provided by the contractor and is considered temporary, and its design is not covered by this guideline. The tieback cable would be attached to a tieback anchorage that is covered by this guideline.

Figure 3. Parapet clamp with outrigger arm. Note the tieback cable at the interior end of the outrigger arm (black arrow). Similar to Figure 2, the clamp is temporary equipment provided by the contractor and outside the scope of this guideline.

Figure 4. Rooftop carriage supporting a platform. The carriage is supported by parallel rails that run along the roof perimeter.
SOURCE: Figure 2 in Hill et al. (2010); copyright ASCE.

Figure 5. Pedestal-type roof anchorage, which may be used as a lifeline anchorage and/or equipment tieback anchorage. The connections of this anchorage to the primary structure are buried in the roofing material, making inspection of the connections impossible without removal of roofing materials.

Figure 6. Lifeline or fall arrest anchorage installed on a parapet/guardrail wall.

Figure 7. Horizontal cables (black arrows) can be used as points of anchorage for vertical lifelines. Loading a wire rope like the one shown with a 5,000 pound vertical lifeline load can create forces in corner and end anchorages many times larger than 5,000 pounds.

Figure 8. Load testing a davit base (black arrow). The horizontal member is a test beam and not part of the dedicated system. The solid white arrow indicates the hydraulic ram. The cribbing under the ram allows the ram to be positioned at the correct elevation and also spreads out the load applied to the roof. The curved white dashed arrow indicates the overturning moment created by the hydraulic ram. Pressure (load) is measured with a calibrated dial gauge or load cell specific to the equipment being used. The test load is applied in the anticipated direction of the in-service load.

Figure 9. Load testing of a davit arm. The black arrows indicate the davit arm. The dotted black arrow points to the reaction test rig. The test is self-contained, and the arm is reacting against itself. The dashed white arrow indicates the hydraulic jack.

Figure 10. Load testing of a lifeline/tieback anchorage. By reacting against another anchorage on the opposite side of the roof, two anchorages can be tested at the same time. In this case, the lifeline anchorages are intended to be used with a lifeline from a davit across the width of the building; hence the test load is being applied in the correct direction.

Figure 11. Tension load testing a threaded insert in a concrete slab (black arrow). In this case, the anchorage is intended to resist a vertical upward force, so that is the direction of the applied test load. A reaction frame is used to move the reactions against the slab away from the insert so that the concrete is tested against breakout. Source: Figure 9 in Larson et al. (2014); copyright ASCE.

Figure 12. Load testing intermediate stabilization anchors on the face of a building. The test pulled from one anchor to the adjacent anchor to generate the required load parallel to the building face, effectively testing two anchors at one time.

Figure 13. Example of anchorages being tested parallel to the roof edge. If these anchorages are to be used when accessing the building façade to the right or left sides of the photo, the test load is not being applied in a direction capable of verifying their suitability for that use. Source: Figure 15 in Larson et al. (2014); copyright ASCE.

Figure 14. Example of appropriately oriented testing of lifeline anchorages perpendicular to the roof edge to the right. The maximum applied moment is equal to that generated by the 5,000-pound horizontal force at the top of the anchorage. The test is slightly more rigorous than the actual factored load would generate because the load applies a net uplift force rather than a net horizontal shear force; this deviation is generally small, conservative, and typically unavoidable.

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CHAPTER 1
Scope

1.1 GENERAL

1.1.1 Title

This document is titled *Façade Access Equipment: Structural Design, Evaluation, and Testing*, hereinafter referred to as this "guideline."

1.1.2 Scope

The provisions of this guideline apply to the structural design, evaluation, and testing of permanently dedicated anchorages and components that support façade access equipment and fall arrest systems.

1.1.3 Intent

The intent of this guideline is to clarify the structural requirements for façade access equipment as a consensus means of complying with related U.S. Occupational Safety and Health Administration (OSHA) provisions.

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CHAPTER 2
Definitions

2.1 GENERAL

2.1.1 Scope

Unless otherwise stated, the following terms shall, for the purpose of this document, have the meanings shown in Section 2.2.

2.1.2 Interchangeability

Verbs used in the present tense include the future. Words stated in the feminine gender include the masculine and neuter, and vice versa. The singular number includes the plural, and vice versa.

2.1.3 Undefined Terms

Terms not defined in Section 2.2 shall have the ordinarily accepted meaning, such as the context implies.

2.2 DEFINITIONS

Anchorage

A structural assembly that resists lateral and/or vertical loads from fall arrest lifelines, fall restraint systems, working lines or tieback lines.

Boatswain's Chair or Bosun's Chair

A single-person seat suspended over the side of a building that is used to access the façade of the building.

Button Guide Anchors

Vertically aligned structural elements that project from the façade of a building and are engaged by vertical tracks mounted on the mobile platform in order to provide the platform with lateral stability.

Carriage

A permanent, moveable rooftop structural assembly that is used to support a suspended platform.

Certify

To express a professional engineering opinion regarding those facts or findings that are the subject of the certification.

Competent Person

A person who is capable of identifying existing and predictable hazards in the surroundings or working conditions, which are unsanitary, hazardous, or dangerous to employees, and who has authorization to take prompt corrective measures to eliminate them.

Construction

Any façade access activities that are not included in OSHA's definition of Routine Maintenance.

Cornice Hook

A metal device that is placed at the roof/façade intersection, and from which platform support lines are suspended. Cornice hooks are curved so as to wrap around elements of the roof and/or wall construction, and either bypass or engage them in order to establish support for attached platform suspension lines. Cornice hooks are similar to parapet clamps, but lack positive mechanical means of attachment to the building.

Davit

A structural assembly that is used to support suspended façade access platforms, and that cantilevers over the edge of a building from a single point of connection to the building.

Davit Base/Davit Socket

A structural element connected to a building that serves as the point of attachment for a davit and that transfers forces and moments from the davit to the building's structural framing.

Drop

A vertical strip of the façade that is accessed by a single platform setup.

Elastic Limit

The structural load beyond which either permanent deformation or failure will occur.

Façade Access Equipment

Any equipment that is used to access the façade of a building. The information in this guideline only regards equipment involving suspended platforms.

Fall Arrest Anchorage

An anchorage that transfers load from a personal fall arrest system to the supporting structure.

Fall Arrest System

See Personal Fall Arrest System.

Fall Restraint Anchorage

An anchorage that transfers load from a fall restraint system to the supporting structure.

Fall Restraint System

An arrangement of structural and mechanical elements that preclude a worker from being in a position where she or he could fall more than 2 feet (0.61 m).

Hoist

A winch-like device that causes a suspended platform to move vertically along a supporting cable.

Horizontal Lifeline

A horizontally oriented rope or cable, usually on a roof, that is used as a point of anchorage for various fall protection and/or fall restraint elements.

Independent

Configured so as to remain intact and serviceable in the event of a failure of any other element or connection that is being relied upon for façade access.

Intermittent Stabilization Anchor

A structural assembly on the façade of a building to which platforms or boatswain's chairs can be attached for lateral restraint.

Lifeline Anchorage

An anchorage that transfers load from a lifeline or personal fall arrest system to the supporting structure.

Outrigger

A beam that is used to support suspended façade access platforms, that cantilevers beyond the face of a building, and that is stabilized by at least two points of support from the building's structure.

Parapet Clamp

A structural device that connects to a parapet wall via mechanical clamping force. Parapet clamps may be used as anchor points for platform suspension lines, lifelines, or tiebacks.

Personal Fall Arrest System

A system of components used to arrest an individual in a fall. It consists of an anchorage, connector, and body harness, and may include a lanyard, a deceleration device, lifelines, or various combinations of these.

Platform

A working surface that can be raised or lowered adjacent to the façade of a building.

Professional Engineer
: An individual who is licensed to practice in one or more engineering disciplines in a particular state as defined by the statutory requirements of the professional registration laws of that state.

Qualified Person
: A person who, by possession of a recognized degree, certificate, or professional standing, or who by extensive knowledge, training, and experience, has successfully demonstrated his or her ability to solve or resolve problems relating to the subject matter, the work, or the project.

Rated Load
: The maximum total load that a structural element or system is allowed to carry when used as intended.

Rope Descent Systems (RDS)
: A suspension system that allows a worker to control their descent along the façade of a building, but provides no means to move upwards.

Routine Maintenance
: Periodic work that is needed to keep the façade functioning as intended, such as window cleaning, re-glazing and replacement of sealants. Almost any other activity is considered by OSHA to constitute "construction."

Service Load
: A load that must be considered in the design, and which has not been modified via application of load factors or safety factors.

Stall Load
: The maximum tension that can be generated by a hoist in its platform suspension line.

Tieback
: A cable or rope that connects a piece of platform support equipment to an independent anchorage point on the building, thus providing a redundant means of support.

Tieback Anchorage
: An independent anchorage used to connect a tieback to the building.

Transportable
: Able to be moved among various locations on a particular building or group of buildings so as to support multiple drops.

Vertical Lifeline
: A line that parallels the travel of a suspended platform, boatswain's chair, or rope descent system and, in the event of a fall, transfers fall arrest loads from a person's harness and lanyard to an anchorage point (e.g., a rooftop fall arrest anchorage or horizontal lifeline).

CHAPTER 3
Design Requirements

3.1 GENERAL

3.1.1 Scope

This chapter provides the basic structural design requirements for façade access equipment.

3.1.2 Design Philosophy

Design of structural elements shall be performed in accordance with nationally recognized standards as provided by the governing building code adopted by the authority having jurisdiction or, if no governing building code exists, as provided by the latest edition of the *International Building Code*.

3.1.3 Design Loads

Unless noted otherwise, loads provided in this guideline are unfactored live loads.

3.2 DAVITS AND DAVIT BASES

3.2.1 Scope

This section covers the design of davits, their supporting elements (i.e., bases or sockets), and related connections.

3.2.2 Design Loads

At a minimum, davits, their supports, and connections to the supported hoist lines shall be designed for an unfactored live load or service load, of 2.5 times the rated load of the supported hoist or the stall load of the hoist, whichever is greater.

If no specific restriction is placed on the stall load of a supported hoist, it shall be assumed that its stall load is 3 times its rated load.

3.3 OUTRIGGERS

3.3.1 Scope

This section covers the design of outriggers, their supporting elements, and related connections.

3.3.2 Design Loads

At a minimum, outriggers, their supports, and their connections to the supported hoist lines shall be designed for an unfactored live load of 2.5 times the rated load of the supported hoist or the stall load of the hoist, whichever is greater.

If no specific restriction is placed on the stall load of a supported hoist, it shall be assumed that its stall load is 3 times its rated load.

Outriggers shall also be designed for lateral stability to prevent roll-over in the event that an accidental lateral load is applied to the outrigger. The accidental lateral load to be considered in the design shall be not less than 44 percent of the rated load of the hoist.

Outriggers that are part of a building's dedicated façade access system must be supported via direct connections with the building structure; counterweights are not permitted. Furthermore, transportable outriggers must have a tieback to an independent anchorage. The tieback shall be aligned with the longitudinal axis of the outrigger, the tieback line strength shall equal or exceed the strength of the primary suspension line, and the tieback anchorage shall be able to carry 2.5 times the rated load of the supported hoist or the stall load of the hoist, whichever is greater.

For contractor-supplied outriggers, rigid counterweights may be used to provide primary stability. The design of these outriggers is not included in this guideline. All transportable- and contractor-supplied outriggers must have tiebacks as described in the previous paragraph.

3.4 ROOFTOP CARRIAGES

3.4.1 Scope

This section covers the design of rooftop carriages.

3.4.2 Design Loads for Rooftop Carriages

The unfactored live load for rooftop carriages, their supports, and their connections to the supported suspension lines shall be the larger of:

1. 2.5 times the rated load(s) of the supported hoist(s), or
2. The stall load(s) of the supported hoist(s).

If no specific restriction is placed on the permitted stall load of a carriage hoist, it shall be assumed that the stall load of the hoist is 3 times its rated load.

When a carriage is being moved, the applicable design forces shall be 1.25 times the load being supported during the move (acting downward) in combination with the wind loads (acting in a horizontal or downward direction such that they are additive to the overturning moment generated by the platform loading) calculated in accordance with ASCE 7-10. It shall be assumed that the carriage experiences wind loads equivalent to that of a parapet, and using a design 3-second gust wind speed of 75 mph.

3.5 TIEBACK ANCHORAGES

3.5.1 Scope

This section covers the design of tieback anchorages, their supporting elements, and related connections.

3.5.2 Design Loads for Tieback Anchorages

The design live load for tieback anchorages should at least be equal to the design live load of the element the tieback cable is intended to support.

3.6 LIFELINES AND FALL ARREST ANCHORAGES

3.6.1 Scope

This section covers the design of lifelines and their anchorages.

3.6.2 Structural Independence

Except as noted below, lifelines and their anchorages shall be structurally independent of the platform support system.

When a boatswain's chair, a rope descent system, or a platform with two points of support is used, every fall arrest system shall have an independent vertical lifeline attached to an anchorage that is independent of the platform and its supporting elements.

When the platform has a back-up suspension line for each primary line and the system meets the conditions specified in (a) through (e) below, a fall arrest system may be attached to designated locations on the platform itself.

a. Each back-up line is attached to a roof anchorage that is independent of the platform's primary support system;

b. The anchorage and platform attachment for each back-up line have been designed to support the same loads as the primary support system.

c. If a primary suspension line or any of its supports or supporting structure breaks, the back-up line shall engage before the original suspension point drops 2 feet (0.61 m);

d. The fall arrest system anchorages on the platform meet the requirements for fall arrest anchorages.

e. If the platform anchorage for the fall arrest system is achieved via a horizontal line (i.e., dog line), the dog line shall be designed as a horizontal lifeline per Section 3.6.4.

When the platform is suspended by more than two primary lines, and the system meets the conditions specified in (f) through (i) below, a fall arrest system may be attached to the platform itself:

f. Each primary platform support line is connected to a rooftop-mounted hoist.

g. Each load-bearing component is designed for the greater of the live loads specified in Section 3.4.2 and the live loads specified in Section 3.6.3. If the failure of any single line, member, or connection would compromise the system's ability to carry these loads, the design loads in Sections 3.4.2 and 3.6.3 shall be doubled for these non-independent elements.

h. The fall arrest system anchorages on the platform meet the requirements for fall arrest anchorages.

i. If the platform anchorage for the fall arrest system is achieved via a horizontal line (i.e., dog line), the dog line shall be designed as a horizontal lifeline per Section 3.6.4.

3.6.3 Design Loads for Vertical Lifelines and their Anchorages

Vertical lifelines and their anchorages shall be designed for a live load of 3,100 pounds (13.8 kN) per simultaneously attached person, in every direction that a fall arrest load may be applied.

3.6.4 Design Loads for Horizontal Lifelines and their Anchorages

Horizontal lifelines shall be designed to resist the effects from a fall arrest load of 3,100 pounds (13.8 kN) per simultaneously attached person in the direction and at the location(s) along the lifeline or lifeline segments that produce the greatest design force in the lifeline.

Anchorages for horizontal lifelines shall be designed for the forces that develop when the specified fall arrest loads are applied. The load(s) shall be applied in the direction and at the location(s) along the lifeline or lifeline segments that produce the greatest design force in each anchorage.

3.7 FALL RESTRAINT SYSTEMS AND ANCHORAGES

3.7.1 Scope

This section covers the design of fall restraint systems and their anchorages.

3.7.2 Design Loads for Fall Restraint Systems and their Anchorages

Fall restraint systems and their anchorages shall be designed for a live load of 1,900 pounds (8.4 kN) per simultaneously attached person, in every direction that the system must preclude a fall.

3.7.3 Design Loads for Horizontal Fall Restraint Systems and their Anchorages

Horizontal cables used in fall restraint systems shall be designed to resist the effects from a fall restraint load of 1,900 pounds (8.4 kN) per simultaneously attached person in the direction and at the location(s) that produce the greatest design forces in the system.

Anchorages for horizontal fall restraint systems shall be designed for the forces that develop when the specified fall restraint loads are applied. The load(s) shall be applied in the direction and at the location(s) that produce the greatest design force at each anchorage.

3.8 WIND SWAY PROTECTION SYSTEMS

3.8.1 Scope

This section covers the design of wind sway protection systems. Wind sway resisted by angulation of the suspension cables is not covered.

3.8.2 Intent

Wind sway protection shall be provided to keep the suspended equipment in continuous contact with the building façade and shall be designed to prevent sudden horizontal movement of the platform.

3.8.3 Vertical Placement

Where intermittent stabilization anchors are provided, the maximum vertical distance between intermittent stabilization anchors shall be three floors or 50 feet, whichever is less.

Where button guide anchors are provided, the anchor design shall be coordinated with the requisite platform-mounted equipment, and anchors must be located so that two guide buttons shall engage each guide track at all times except for at the location of initial engagement.

3.8.4 Design Load

Wind sway protection systems shall be designed for the larger of the following loads:

- A wind load of 600 pounds (2670 N) centered on the platform in any horizontal direction; and
- A wind load corresponding to the force created by a 75 mph (34 m/s) wind on the scaffold (for strength design wind loads) in any horizontal direction. Wind loads shall be calculated using the American Society of Civil Engineers' *Minimum Design Loads for Buildings and Other Structures (ASCE/SEI 7-10)*.

If a platform is to remain suspended on the side of a building without operators, its attachment shall be able to sustain the wind loads required by the building code for permanent structures.

3.9 PLATFORMS

3.9.1 Scope

This section covers the design of platforms.

3.9.2 Design Loads

Platforms that are part of a rooftop carriage or permanent installation of a building shall provide for a minimum live load of 250 pounds (1112 N) for each occupant.

CHAPTER 4
Evaluation and Testing

4.1 GENERAL

4.1.1 Scope

This chapter governs the evaluation and testing of façade access systems.

4.1.2 Intent

The intent of evaluation and testing of façade access systems is to confirm whether or not the systems meet the structural requirements of this guideline, OSHA, and any other state or local agencies having jurisdiction.

4.1.3 When Required

Structural components of the façade access system shall be evaluated and/or tested for purposes of certification by a professional engineer:

- Upon initial installation;
- When significant modifications or repairs are performed;
- If use and/or exposure have led to concerns regarding the integrity of certain structural elements or the system as a whole; and
- If documentation of the initial certification is not available or valid, or if initial certification was not performed.

4.2 EVALUATION AND TESTING

4.2.1 Evaluation

Evaluation shall be based on an appropriate combination of visual observations, calculations, materials testing, and/or load testing.

4.2.2 Visual Observations and Calculations

When evaluating façade access systems, all structural components of the system and all structural components that provide primary gravity support of façade access or fall arrest systems shall be visually observed. Calculations shall be performed in accordance with approved national standards to confirm that the design and construction meets the minimum structural requirements of this guideline and OSHA. Measurements of the various components shall be made as necessary and appropriate to verify assumptions made in any calculations.

If some of the structural components described above cannot be visually observed to a level necessary to confirm structural adequacy, load testing shall be undertaken, as described in 4.2.4.

4.2.3 Materials Testing

Materials testing shall be performed as necessary and appropriate to verify the physical properties of structural materials. Nondestructive testing shall be performed as required to verify the size, quality, and condition of welds.

When the results of materials testing are inconclusive (i.e., when it is not possible to verify with reasonable assurance the relevant properties of the existing materials), load testing as described in 4.2.4 shall be considered as a method to confirm acceptable performance.

4.2.4 Load Testing

Load testing shall be performed when required by this section or when the engineer responsible for the evaluation determines it is necessary to confirm that the system conforms to the minimum OSHA strength requirements.

4.2.4.1 Testing Plan

Prior to implementing structural load testing, the engineer in responsible charge of the testing shall develop a plan outlining the test procedures and equipment, applicable loads, and acceptance/failure criteria. This review shall also include consideration of suitable reaction points for chain hoists, hydraulic rams, and other equipment necessary to carry out the testing. The ability of building components loaded by test equipment (e.g., roof slabs, exposed roof framing, penthouses) to support the reaction loads generated during the testing shall also be evaluated.

4.2.4.2 Loading

At a minimum, test loads used to verify adequate capacity of façade access equipment shall equal the full factored design loads. Loads shall be applied in a manner that verifies adequate strength in each direction for which the system or component may experience the design load.

Loads shall be applied at appropriate rates and increments, as determined by the engineer. In general, the direction of test loads shall be in the same direction as expected for the in-service loads.

4.2.4.3 Monitoring of Deflection

Deflection of the system or component shall be monitored during load testing. Elements that experience significant inelastic behavior that adversely affects their ability to carry load shall be replaced.

4.2.4.4 Repair of Damage

Any structural components that experience significant damage during the load testing shall be repaired or replaced. Any structural components that do not meet the minimum OSHA requirements shall be taken out of service until they are strengthened or replaced. Any architectural damage that occurs as a result of load testing shall be repaired.

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CHAPTER C1
Scope

C1.1 GENERAL

C1.1.2 Scope

Only *structural engineering* provisions are addressed in this guideline. Further, only provisions relating directly to the façade access structures and components that are permanently attached to the building are addressed herein. This guideline is not intended to address contractor-supplied equipment, operational issues, mechanical engineering issues, or electrical engineering issues related to façade access.

Examples of anchorages and components covered by this guideline include davit bases and davit arms that support façade access equipment over the side of a building, lifeline or fall arrest anchorages that are designed to "catch" a falling worker, and tieback anchorages that are designed to act as back-up supports for temporary outriggers. This guideline also addresses the associated design forces for structural elements that provide support for these anchorages and components.

C1.1.3 Intent

The provisions within this guideline are based on the structural engineering requirements of the Federal Occupational Safety and Health Agency (OSHA) related to façade access equipment. Unless noted otherwise, requirements of state and local jurisdictions are not included in this guideline. Many OSHA requirements relating to façade access issues contain language devoid of commonly understood structural engineering design terminology. This guideline is intended to convey the generally understood meaning of the OSHA requirements in a form that structural engineers can readily use and understand. In addition, the unfactored design loads discussed in the guideline typically match those in the 2015 *International Building Code*.

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CHAPTER C2
Definitions

C2.1 GENERAL

C2.1.1 Scope

This section is intended to provide clear definitions for terms used by OSHA, some of which are not commonly encountered in the structural engineering discipline or may have a number of different commonly accepted definitions.

C2.1.2 Interchangeability

The intent of the guideline is for most verbs to be in the present tense, the gender of pronouns to be interchangeable, and for numbers to be either singular or plural as appropriate.

C2.1.3 Undefined Terms

Any commonly accepted dictionary definition can be used to define terms that are not defined in this guideline.

C2.2 DEFINITIONS

Anchorage

See Figures 5 and 6 in the introduction for examples of anchorages.

Boatswain's Chair or Bosun's Chair

Commonly, a boatswain's (or bosun's) chair has been defined as a platform that can be raised and lowered, as opposed to Rope Descent Systems, which, although they also use a chair, can only go down.

Button Guide Anchors

Figure 3 in Appendix B of OSHA §1910.66 provides a sketch of a button guide stabilization system.

Carriage

See Figure 4 in the introduction for an example of a carriage.

Certify

Engineers are sometimes called upon to “certify” that façade access equipment complies with OSHA requirements. This definition essentially matches the definition in the California Professional Engineers Act, which explains that the term “certify” means to provide a “professional [engineering] opinion”. Certification does not constitute a warranty or guarantee, either expressed or implied.

Competent Person

The term “competent person” is defined in OSHA §1910.66.

Construction

See Routine Maintenance.

Davit

Figure 1 in the introduction shows an example of davits.

Davit Base/Davit Socket

Figures 1 and 8 in the introduction show davit bases.

Elastic Limit

For ductile elements, when the elastic limit is exceeded, the element will begin to permanently deform. For brittle elements, the elastic limit represents the ultimate capacity.

Façade Access Equipment

Other equipment such as aerial lifts and ground-supported scaffolding can be used to access façades but their design and use are not considered herein.

Fall Arrest Anchorage

The term “fall arrest anchorage” is synonymous and interchangeable with the term “lifeline anchorage”. Figure 5 in the introduction shows a fall arrest anchorage.

Fall Restraint Anchorage

The design forces for fall *restraint* systems are less than the design forces for fall *arrest* systems. See Section 3.7 for more information.

Fall Restraint System

Although OSHA has not formally adopted requirements for a system that precludes workers from falling, they have issued recommendations that govern the design of these systems. In order to qualify as a fall restraint system, the maximum fall distance for a worker must be 2 feet (0.61 m).

Hoist

Figure 1 in the introduction shows examples of hoists.

Horizontal Lifeline

Depending on the design, horizontal lifelines can be used as points of anchorage for vertical lifelines, fall restraint devices or lanyards. Figure 7 in the introduction shows an example of a horizontal lifeline.

Independent

This definition is intended to ensure substantial separation between "independent" items (e.g., primary and secondary support systems). In the event that the primary support system fails, the intent is that a functioning backup remains, configured so that it would be extremely unlikely for both systems to be compromised at the same time. Tying a lifeline to a davit base that is being used to support a suspended work platform does <u>not</u> meet the intent of the requirement, even if the davit base were designed to resist the full factored load from the work platform plus the full factored load from the lifeline, because failure of the davit base would mean failure of the lifeline anchorage as well. However, there may be situations where both the primary and secondary support systems rely on the same structural element, such as a primary structural column or beam; the intent could be met for this condition as long as the design of this element is not governed by the façade access loads.

Intermittent Stabilization Anchor

Figure 2 in Appendix B of OSHA §1910.66 provides a sketch of an intermittent stabilization system.

Lifeline Anchorage

The term "lifeline anchorage" is synonymous and interchangeable with the term "fall arrest anchorage". Figure 5 in the introduction shows a lifeline anchorage.

Outrigger

Figure 2 in the introduction shows an example of an outrigger.

Parapet Clamp

Figure 3 in the introduction shows a typical parapet clamp. OSHA states that parapet clamps require a tieback. This guideline assumes that OSHA intends only those parapet clamps providing primary platform support require tiebacks. In the event that a parapet clamp is being used as a tieback or a lifeline support, it would not require a separate tieback. It is important that both the parapet clamp and the parapet meet the minimum capacity requirements for these purposes.

Personal Fall Arrest System

This definition is from OSHA §1910.66 App C.

Platform

See Figure 4 in the introduction for an example of a platform.

Qualified Person

This definition is from OSHA §1926.32. A professional engineer who is familiar with façade access systems would be considered to be a qualified person by OSHA. The requirements to be considered a *qualified* person are significantly more stringent than those to be considered a *competent* person.

Rated Load

Rated loads represent the upper weight limit of what is considered acceptable for equipment used to access a façade. While they are consistent with what the structural engineering profession has historically called "service" or "unfactored" loads, rated loads do not cover all applicable conditions that façade access equipment may actually experience in service.

Hoists typically have a rated load that is assigned by the manufacturer (e.g., 1000 pounds, 1250 pounds, or 1500 pounds); this load is used to design the elements that support the hoist, regardless of the rated load of the platform.

Also see definition and commentary on service load.

Rope Descent Systems (RDS)

Rope descent systems typically include use of a boatswain's chair platform for the worker.

Routine Maintenance

According to OSHA, activities such as painting, hanging signs, and hanging holiday lights, for example, are considered to be construction activities, whereas window washing, re-glazing, and replacing sealant would be considered routine maintenance.

Service Load

Service loads include rated (static gravity) loads as well as lateral loads, dynamic effects and other loads that can reasonably be expected to occur, even if rarely, during normal operations. Examples include loads from severe winds, forces generated by platforms falling a short distance (e.g., after hanging up on an obstruction during a descent), and forces generated by hoists when platform ascent is prevented by some form of hang-up or other obstruction. Therefore service loads in this guideline will never be less than rated loads.

Stall Load

According to OSHA §1910.66(f)(3)(i)(M) and §1926.451(a)(5), the stall load of a hoist is permitted to be as large as three times its rated load. Unless it can be assured that a system will only be used with hoists that have lesser stall loads, it should be assumed that hoist stall load is three times the rated load.

Tieback

OSHA requires certain types of platform support equipment, such as parapet clamps, cornice hooks and counterweighted outrigger beams, to have a connection to the structure that is *independent* of the equipment's primary means of support.

Tieback Anchorage

Figure 5 in the introduction shows an anchorage that may be used to secure a tieback.

Transportable

Transportable elements are dedicated elements designed for a particular building or group of buildings.

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CHAPTER C3

Design Requirements

C3.1 GENERAL

C3.1.2 Design Philosophy

While OSHA defines the loading that structural elements need to be able to support, OSHA specifications are not consistent with commonly used structural engineering literature and standards. In addition, OSHA does not specify how element strengths are to be established. To facilitate use by structural engineers, the loads specified in this guideline have been defined so that application of building code load factors will essentially replicate OSHA-specified load requirements. Building codes also provide, either directly or by reference, appropriate methods for determining element capacities. As discussed in Chapter 4, it may be desirable to design façade access elements to remain elastic under the full factored loads.

C3.1.3 Design Loads

The intent of this guideline is for the provided design loads, when used with the aforementioned design standards, to produce a design that is consistent with the intent of the OSHA regulations and achieves confidence levels consistent with common structural engineering design standards. The unfactored design loads provided herein generally match those in the 2015 *International Building Code* for design of façade access equipment.

C3.2 DAVITS AND DAVIT BASES

C3.2.1 Scope

OSHA §1910.66(f)(3)(iii) contains the structural requirements for davits used for routine maintenance.

C3.2.2 Design Loads

OSHA §1910.28(a)(4) requires that platforms and their supports be designed to be capable of supporting without failure at least four times the rated load. OSHA §1910.66 contains a similar requirement.

OSHA §1926.451(d)(1), which governs all equipment used for purposes other than routine maintenance, requires that all suspension support devices such as davits, outrigger beams, and parapet clamps be able to support the greater of four times the rated load and 1.5 times the stall load of the hoist. According to OSHA, activities such as painting, hanging signs, and hanging holiday lights, etc. are considered to be construction activities, whereas window washing, re-glazing, and replacing sealant would be considered routine maintenance.

The 2015 *International Building Code* contains a requirement to design davits and davit bases for the larger of the stall load or 2.5 times the rated load. Consequently, this guideline requires designing for the larger of the two loads.

Both a hang-up-and-fall scenario during descent and a hoist overload due to “snagging” of the platform during upward movement of the platform can generate tension in the suspension lines that can far exceed the weight of the supported platform and its contents.

According to OSHA, all reasonably anticipated, critical forces acting on a davit can be related to properties of the supported hoist. The maximum permitted normal gravity load is equal to the hoist’s rated load. If greater forces result from hang-up-and-fall situations, they are proportional to the weight being carried by the hoist, which is limited to the rated load. Finally, the davit force generated by a hoist pulling on a platform that is prevented from moving by some form of obstruction is limited to the hoist’s stall load.

The 2.5 multiplier on rated load in this guideline is intended to represent the impact effects of a hang-up-and-fall situation on a fully loaded platform. Since OSHA permits hoists to stall at loads as high as 3 times the rated load, this stall load must be used in the design of davits when no additional restrictions on stall load are specified.

These requirements, when combined with the live load factor specified in most building codes (typically 1.6), will result in a factored davit design load of 4.0 times the rated load or 4.8 times the rated load for systems where stall loads are not specifically defined.

C3.3 OUTRIGGERS

C3.3.1 Scope

OSHA requirements for outriggers used for routine maintenance are provided in §1910.66 and §1910.28. When supporting scaffolds used for work other than routine maintenance, OSHA §1926.451 provisions apply. The structural requirements for outriggers are essentially the same as for davits, except that *transportable* outriggers (i.e., outriggers that can be moved among various locations on the building or within a group of buildings) must also have a tieback or equivalent positive connection to the structure, and specific lateral load requirements are given.

C3.3.2 Design Loads

See the discussion regarding davit design forces for commentary regarding these loads.

Since outriggers are cantilevers that are typically strongest in bending in the vertical axis and relatively weak in bending in the horizontal axis, an accidental lateral load is considered in addition to vertical loads to ensure that the outriggers do not experience lateral instability. OSHA §1910.66(f)(3)(ii)(E) covers this condition, though it is not clear whether the accidental load is an ultimate load or a service load. However, since other outrigger loads provided by OSHA are ultimate loads, it is reasonable to assume that the accidental lateral load is an ultimate load as well. To this end, the load specified in this guideline is the OSHA-specified load divided by 1.6; as with all of the design loads in this guideline, this is a service load and should be increased by a load factor of 1.6 to comply with strength design provisions.

The requirements and limitations associated with counterweights and tie-backs come directly from OSHA provisions.

As with the design loads for davits and davit bases, the 2015 *International Building Code* contains a requirement to design outriggers and their supports for the larger of the stall load or 2.5 times the rated load. Consequently, this guideline requires designing for the larger of these two loads.

C3.4 ROOFTOP CARRIAGES

C3.4.1 Scope

OSHA §1910.66 provides the requirements for rooftop carriages used for building maintenance.

C3.4.2 Design Loads for Rooftop Carriages

OSHA requires that carriages and their supports be designed to resist at least 1.5 times the stall load of the hoist. While the requirement that carriages and their supports be designed for 4 times the rated load of their supported hoists does not appear in OSHA requirements, this appears to be an oversight, since hang-up-and-fall scenarios and "snagging" of the platform during upward movement of the platform can both occur; consequently, this requirement has been included in the guideline.

OSHA §1910.66(f)(3)(i)(G)(1) covers lateral stability while the carriage is traversing its track. OSHA requires that "the stability factor against overturning shall not be less than two for horizontal traversing of the carriage, including the effects of impact and wind." Using an unfactored service load of 1.25 times the supported load (acting downward) in combination with a load factor of 1.6 is consistent with the OSHA requirement for a "stability factor" of 2.0 for the supported load.

For wind loads, OSHA §1910.66 has a general requirement that when in service, wind loads caused by a wind event characterized by a 50 mph wind speed at an elevation of 30 ft be included.

The OSHA requirements were written when code wind loads were based on a fastest-mile wind speed. Since then, code wind loads have switched to a three-second gust and have moved to a strength-design basis. The OSHA requirements have not changed during this same time period. Thus, OSHA's intent is not clear. The approach in this guideline produces a design that is consistent with the intent of the OSHA regulations and achieves confidence levels consistent with common structural engineering design standards. The wind speeds and forces provided in this guideline are based on the loads in ASCE/SEI 7-10 and the load factors in the 2012 *International Building Code* (i.e., strength-design wind loads that have a load factor of 1.0). If ASCE/SEI 7-05 and the 2009 *International Building Code* or earlier versions are being used, the wind loads provided in this guideline can be reduced by a factor of 1.6 to balance the 1.6 wind load factor used in those standards.

Wind loads should be applied in the direction that creates the most onerous condition for the stability of the carriage.

C3.5 TIEBACK ANCHORAGES

C3.5.2 Design Loads for Tieback Anchorages

While OSHA §1910.66(f)(3)(ii)(H) requires the tieback rope to have a strength equivalent to that of the suspension rope, it does not actually specify a design load for the tieback anchorage itself.

Logically, the tieback anchorage should be designed for no less than the design load of the element the tieback cable is supporting.

Tieback anchorages frequently serve two functions; tieback anchorages and lifeline anchorages, although not concurrently. As a result, these anchorages should be designed for the greater of the design load of the element it supports as a tieback or the design load for a lifeline anchorage.

C3.6 LIFELINES AND FALL ARREST ANCHORAGES

C3.6.1 Scope

The design of the actual lifeline rope and connections of the rope to the lifeline anchorage and to the user are not covered in this guideline.

C3.6.2 Structural Independence

A failure of the primary suspension system should not impair, impede, or preclude the functioning of the fall arrest system. Fall arrest anchorages must be connected to structural elements whose principal purpose is unrelated to the support of the primary suspension system. For example, it may be possible to connect lifelines from one side of the building to unused davits on the opposite side of the building but lifelines should not be connected to the same davit or davit bases that are being used to support the platform.

In general, the lifelines should be completely independent from the platform support system so that if a primary suspension line or its supports should fail, the users will be supported by the independent lifelines. When a back-up suspension system is provided and it is completely independent of the primary suspension system, lifelines can be anchored to designated locations on the platform.

When the façade access system includes platform-mounted hoists, the secondary suspension lines must connect to the platform independently of the hoists, and they must be anchored to the building in a manner that does not rely on the integrity of structural elements whose primary purpose is to provide support for the platform during normal operations (e.g., davits, davit bases, and outriggers).

Systems that have more than two active suspension lines and satisfy the criteria listed in Items (f) through (j) of Section 3.6.2 provide reliability comparable to that which is provided by systems with back-up suspension lines as outlined in Items (a) through (e) of Section 3.6.2, which means the requirements for lifeline independence can be comparably relaxed. For these systems, there is no distinction between primary and backup suspension lines. To achieve a reliability that is reasonably comparable to completely independent suspension systems, the design forces shall be doubled for critical elements whose failure would compromise the ability of the system to carry the required loads (i.e., the elements that are not structurally independent).

C3.6.3 Design Loads for Vertical Lifelines and Their Anchorages

In general, OSHA §1910.66 and §1926.502 require lifeline anchorages to be capable of supporting a load of at least 5,000 pounds (22.2 kN) per attached person. Although OSHA requirements are not written using common structural engineering terminology, use of a design live load of 3,100 pounds (13.8 kN), when combined with a live load factor of 1.6, results in a total factored load of 4,960 pounds (22,1 kN), which essentially matches OSHA's requirements for lifeline anchorages. Although this load might appear excessive, it is intended by OSHA to address the fall arrest loads that can and do reasonably occur in typical lanyards for body harnesses, and which are highly variable. OSHA allows stopping forces as high as 2,520 pounds (11.2 kN) to be generated by a person free-falling six feet. Sometimes people weigh more than the weight assumed by OSHA, or they may fall more than six feet, and lifeline anchorages represent the user's last hope of avoiding a potentially fatal fall when something has gone wrong with the primary suspension system. So the effective factor of safety of two - from an ideal design load of 2,520 pounds (11.2 kN) to an ultimate design load of 5,000 pounds (22.2 kN) - is what OSHA deems necessary to provide an acceptable level of safety.

While OSHA permits an exception to the 5,000 lbs per person capacity requirement, that exception is valid only when a qualified person supervises the system's design, installation, and use. Unless it can be assured that all of these criteria will be consistently satisfied (e.g., in a manufacturing facility where all fall protection usage is supervised by a plant safety engineer), the default design load of 3,100 lbs (13.8 kN) should be used. The 2015 *International Building Code* will not include this exception in the live load section, primarily because of OSHA's requirement that a qualified person supervise every use of the system. This requirement was not considered to be cost-effective or a reasonable alternate for nearly all applications.

C3.6.4 Design Loads for Horizontal Lifelines and their Anchorages

Horizontal lifelines are often used to provide flexibility for worker movement and location. In horizontal lifeline systems, the forces generated in the line and its supports can be much larger than the applied arresting forces. The design of horizontal lifelines is substantially more complex than the design of vertical lifelines. Forces in horizontal lifelines and the associated anchorages and supports depend not only on the arresting forces, but also on the physical characteristics of the installed system. Initial line tension, line stiffness, anchorage location, line path, and other features must all be carefully considered.

See commentary for vertical lifelines concerning situations where lesser design loads are permitted.

Load limiting devices, or shock absorbers, are often used in practice with horizontal lifelines. In most applications, the effects of load limiting devices should be viewed with skepticism unless it is a very simple application. Most manufacturers only warrant the performance of these devices for the simplest of applications: a simple span (two-support) lifeline with no intermediate anchorages supporting a single occupant, for example. Regardless, any device in line with a horizontal lifeline must be able to support the full effects of the factored live loads applied in the direction of a fall.

C3.7 FALL RESTRAINT SYSTEMS AND ANCHORAGES

C3.7.1 Scope

The design forces for fall *restraint* systems are less than the design forces for fall *arrest* systems. Thus, fall restraint anchorages may not be compatible with a fall arrest system. If there is a chance that a fall restraint anchorage may be inadvertently used as part of a fall arrest system, either the fall restraint anchorages should be clearly marked to differentiate them from fall arrest anchorages to prevent misuse, or the fall restraint anchorages should be designed for the increased forces associated with fall arrest systems.

The design of the connection of the fall restraint system to the user is not covered in this guideline.

C3.7.2 Design Loads for Fall Restraint Systems and their Anchorages

OSHA does not have any formal provisions that govern the design of fall restraint systems; however, in 1995, OSHA issued a letter of interpretation that suggested that fall restraint systems be designed for a minimum load of 3,000 pounds (13.3 kN). This load has been converted from an ultimate or factored load to an unfactored load of 1,900 pounds (8.4 kN) by dividing by a load factor of 1.6, which is the typical live load factor applied by common strength design methods.

This design load for fall restraint systems is lower than the design load for fall arrest systems because a fall restraint system must begin restraining the worker before she or he falls more than 2 feet (0.61 m), while a fall arrest system can be used in situations where up to 6 feet (1.83 m) of unrestrained fall is permitted.

C3.7.3 Design Loads for Horizontal Fall Restraint Systems and their Anchorages

Horizontal cables are often used to provide flexibility for worker movement and location. In horizontal fall restraint systems, the forces generated in the line and its supports can be much larger than the applied restraint forces. Forces in horizontal restraint cables and the associated anchorages and supports depend not only on the restraint forces, but also on the physical characteristics of the installed system. Initial line tension, line stiffness, anchorage location, line path, and other features must all be carefully considered.

C3.8 WIND SWAY PROTECTION SYSTEMS

C3.8.1 Scope

Wind sway protection systems are located on the building exterior and are used to provide lateral restraint against wind forces for suspended platforms. Continuous vertical tracks or discrete anchors can be used to provide this support.

The tracks or anchors are used to stabilize the platform or its suspension cables either continuously or at discrete points over the height of the building.

Angulated (angled) cables can also be used to stabilize platforms. Requirements for angulated cables can be found in OSHA §1910.66(e)(2)(iii)(C) and §1910.66(e)(2)(ii) but are beyond the scope of this guideline.

C3.8.2 Intent

This explanation is taken from OSHA §1910.66(e)(2)(iii)(A).

C3.8.3 Vertical Placement

These requirements are taken from OSHA §1910.66(e)(2)(iii)(A)(1), §1910.66(e)(2)(iii)(B)(1) and §1910.66(e)(2)(iii)(B)(4).

C3.8.4 Design Load

Structural requirements for intermittent stabilization systems are found in OSHA §1910.66(e)(2)(iii)(A)(5). Specifically, the wording states that "the intermittent stabilization system building anchors and components shall be capable of sustaining without failure at least four times the maximum anticipated load applied or transmitted to the components and anchors. The minimum design wind load for each anchor shall be 300 pounds (1334 N), if two anchors share the wind load." Further, OSHA §1910.66(f)(1)(iv) states that "equipment that is exposed to wind when in service shall be designed to withstand forces generate[d] by winds of at least 50 miles per hour (22.4 m/s) for all elevations."

These requirements were written when code wind loads were based on a fastest-mile wind speed. Since then, code wind loads have switched to a three-second gust, and then even more recently switched to strength-design basis. The relevant OSHA requirements have not changed at all during this same time period. Thus, OSHA's intent is not clear. The suggested approach provides a rational application of the current OSHA provisions. The wind speeds and forces provided in this guideline are based on the loads in ASCE/SEI 7-10 and the load factors in the 2012 *International Building Code* (i.e., strength-design wind loads that have a load factor of 1.0). If ASCE/SEI 7-05 and the 2009 *International Building Code* or earlier versions are being used, the wind loads provided in this guideline can be reduced by a factor of 1.6 to balance the 1.6 load factor in those standards.

C3.9 PLATFORMS

C3.9.2 Design Loads

Powered platforms must be designed for these loads per OSHA §1910.66(f)(1)(ii).

CHAPTER C4
Evaluation and Testing

C4.1 GENERAL

C4.1.2 Intent

Building owners are required to certify to the users of façade access systems that the systems meet all of the applicable capacity requirements specified by OSHA. When questions regarding structural requirements arise, appropriately qualified professional engineers are often asked to verify compliance. This section provides guidance for providing valid certifications of structural integrity.

C4.1.3 When Required

Although façade access systems are required to be inspected by a *competent* person prior to every use and at intervals not exceeding 12 months, OSHA specifically calls for evaluation of building maintenance equipment by a *qualified* person at certain critical periods in a system's life: upon initial installation, when significant modifications or repairs are performed, and if use and/or exposure have led to concerns regarding the integrity of certain structural elements or the system as a whole.

OSHA §1910.66(g)(1) states the following, "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 this standard, and that all safety and operating equipment is functioning as required. A similar inspection and test shall be made following any major alteration to an existing installation." 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.

"*Applicable requirements*" include structural requirements. Therefore, newly installed elements and newly modified elements must be tested to verify compliance with OSHA structural requirements. Where element performance requires significant inelastic deformation, testing must be limited to something less than the OSHA-specified minimum capacity (lest the equipment be rendered unusable), which means load testing alone will not be sufficient for verifying compliance. This is one very good reason why elements should be designed to sustain applicable loads elastically. When this is not done, verification of adequate strength typically requires much more effort, and often includes measures such as exposure and careful examination of key elements, testing of certain components and analysis of others, etc.

When evaluating existing elements to verify continued compliance, testing is not always required; however, testing is often the most efficient approach, especially when obtaining the information needed to perform reliable analyses requires removal of roofing materials and/or other building components.

In many cases, the need for testing and determination of test protocols requires careful consideration by a *qualified* person.

C4.2 EVALUATION AND TESTING

C4.2.1 Evaluation

The purpose of evaluating a façade access system is to assess whether it meets the minimum structural requirements of this guideline and OSHA.

C4.2.2 Visual Observations and Calculations

Visual observation of critical components is essential to understanding the façade access system. Damage and deterioration should be noted and evaluated, via calculations if appropriate.

In many cases, critical structural components may be located under or obscured by architectural components such as roofing, roof deck construction, or ceiling finishes. Any structural evaluation must consider the actual condition of hidden structural components. One option is to remove the elements that obscure the structural elements of interest. However, this is often costly and disruptive. When conditions permit, load testing often represents a more efficient alternative.

C4.2.3 Materials Testing

If the material properties of a particular element are unknown, it may be appropriate to perform materials testing on a sample or samples to better determine the properties. In some cases, it may be sufficient to assume a lower bound material strength and evaluate the element using this lower bound strength. If the element is deemed adequate with a conservative estimation of material strength, material testing may not be required.

If the element is found to be deficient assuming a conservative estimate of material properties, then materials testing or proof testing may be considered to confirm acceptable performance.

C4.2.4 Load Testing

Proof load testing is typically the easiest way to verify that a system meets the minimum strength requirements. A primary exception includes systems where significant inelastic deformation is needed in order to mobilize the required strength. In such instances, analytical means must be employed, even if substantial demolition is necessary to obtain the required information. In some instances, materials testing or testing of specific elements of a system (e.g., anchor bolts or concealed welds) may still be required.

C4.2.4.1 Testing Plan

Proof load testing not only imparts significant loadings on elements of the façade access systems but may also impart significant loads on existing building framing in ways that may not have been considered in its original design. It is incumbent upon the qualified person to review available information on these building components to confirm their ability to support the anticipated loadings generated during the testing. For example, a light gauge metal roof deck may not have adequate capacity to support the downward force generated by the hydraulic jack shown in Figure 7 of this guideline. An exposed structural column supporting HVAC equipment may not possess adequate flexural strength in weak-axis bending to serve as a reaction point for a 5,000 pound load generated during testing of a nearby lifeline anchor. These items must be considered as appropriate by the qualified person responsible for the testing.

C4.2.4.2 Loading

For a discussion regarding why it is required to load test to the full factored load, please see the introduction.

In general, test loads for these systems are applied relatively quickly (i.e., over the course of a minute or two), though not necessarily at the very rapid rate that say, a fall arrest or over-tensioning due to a hang-up might occur. Structurally, differences between the rate of applied test loading and the rate of actual loading are unlikely to result in a different or unconservative outcome, as structural materials tend to be slightly stronger when loaded under impact loads as compared to a slightly slower load test regimen. Generally, it is prudent to load the component or system being tested twice. This is due to the fact that most systems will not have sustained loads as high as the test loads, in which case some non-recoverable but not damaging movement or "set" may be expected (e.g., slippage that occurs as bolts go into bearing). The initial loading should be done slowly enough to permit observation of instability should it occur. Typically, load increments of 10 to 20 percent of the total load are sufficient. If the full test load can be carried in a stable manner, the loading should be removed and re-applied while monitoring deformations so as to confirm linear elastic behavior after any initial "set" has been removed.

In general, test loads should be applied in the same direction as the expected in-service loads to ensure that the various structural components have the required capacity in the directions that they will be loaded in-service. For example, Figure 8 of this guideline shows a davit base being load tested with a moment in the same direction as the expected in-service moment. Figure 13 shows a load test of two lifeline anchorages that does <u>not</u> appear to be properly configured; the anchorages should have been tested in the same direction as the tension from the lifeline (i.e., perpendicular to the building edge, not parallel). Conversely, the lifeline anchorage being tested in Figure 14 is being loaded in the correct direction with a moment that matches the magnitude and direction of the moment that would be caused by application of a fall-arrest load at the top of the anchorage (i.e., towards the edge of the building).

C4.2.4.3 Monitoring of Deflection

Monitoring deflections allows the engineer overseeing the test to confirm whether or not the tested components remain elastic. Elements that remain elastic will be able to sustain repeated applications of the load in a stable manner. If significant inelastic behavior is observed during successive applications of the test load, this may indicate that the component or system is defective or deficient. Alternately, the component or system may have been designed so that it requires significant inelastic behavior to achieve the minimum required capacity, in which case, as discussed above, proof load testing may not be an appropriate method to assess the component's or system's capacity.

As discussed in the commentary to Section 4.2.4.2, some minor inelastic deformation or "set" may be expected during the first application of the test load. Therefore, deflection monitoring results from subsequent load cycles should be used to determine whether or not the system is stable.

A key metric is the deflection at peak loading under successive applications of the test load. If peak deflections are comparable from application to application, then by definition, the element is sustaining the loads in a stable manner.

C4.2.4.4 Repair of Damage

It is important to recognize that due to its nature, load testing may result in damage, and that damaged elements will need to be addressed. Typically, damage indicates that the component or system being tested was not adequate and did not meet OSHA's minimum structural requirements; in such cases, the component or system must be taken out of service until it is strengthened or replaced.

Generally, the magnitude of loading applied during typical tests is relatively modest and the effects can be mitigated through use of cribbing and other measures to spread out the loads; however, some damage to finishes, roofing and other architectural elements may still occur. The potential for this type of damage should be considered in any test plan and should be discussed with the building owner prior to testing. Regardless, incidental damage caused by load testing is typically far less severe than would be expected to be caused by an intrusive investigation aimed at exposing and verifying hidden components and connections.

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