Design and Load Testing of Façade Access Equipment

by Jonathan E. Lewis, Gwenyth R. Searer, and Stephen B. Schmitt, Jr.

Fig. 1: Building maintenance unit

Façade access equipment on mid- and high-rise buildings is used for maintenance activities, such as window washing and façade inspections, and construction activities, such as painting and façade repairs. In the United States, strength provisions for this equipment are specified by the Occupational Safety and Health Administration (OSHA), state and local codes, and the 2015 and 2018 *International Building Code* (IBC)[1]. OSHA requires such equipment be inspected and tested to verify compliance with applicable requirements, including capacity requirements. Load testing is commonly used to satisfy OSHA requirements and verify the strength of the equipment. Load test practices vary widely in the industry, with some engineers using test criteria that fall 50 percent short of their desired aim. Because design loads for this equipment are relatively new to the building code, it is important to understand how to properly design and load test façade access equipment. An upcoming façade inspection or repair project is an opportune time to improve façade access and compliance with OSHA regulations.

TYPICAL FAÇADE ACCESS EQUIPMENT

Façade access equipment, also referred to as exterior building maintenance equipment, comes in a variety of forms, from large crane-like machines called building maintenance units or BMUs (Fig. 1), to portable davit systems (Fig. 2) that can be erected at discrete points on the roof, to individual anchorages (Fig. 3) that support rope descent systems, worker lifelines, or tiebacks from temporary suspension equipment such as parapet clamps. Façade access equipment can be provided either by the building (e.g., BMUs, davit systems, anchorages, and dedicated work platforms) or by the contractor (e.g., parapet clamps, counterweighted outrigger beams, and transportable platforms). Façade access equipment has specific requirements for design and testing; many engineers and architects have historically been unaware of them.

DESIGN OF FAÇADE ACCESS EQUIPMENT

Two main subcategories of façade access equipment exist: equipment that supports powered motors or hoists for raising/lowering platforms; and equipment that supports non-powered components such as rope descent systems or personnel lifelines.

Loads for Components that Support Hoists

OSHA requires components that support a hoist to be able to resist at least 4.0 times the "rated load" of the hoist. "Rated load" is the safe working load that the hoist is intended to lift and can range from 750 to 1,500 lbs (340 to 680 kg) for typical suspended window washing platforms. Equipment that is used to perform "construction" activities—such as concrete façade repairs—is also required by OSHA to be able to resist 1.5 times the "stall load" of the hoist. OSHA permits stall loads to be as high as 3.0 times the rated load, so 4.5 times the rated load of the hoist is an upper bound. These load factors may seem large, but the loads themselves can include significant dynamic effects and are generated by machines capable of imparting forces much larger than the load being lifted.

Where adopted, the IBC and ASCE/SEI 7-16[2] treat loads from hoists as live loads, and components that support hoists for façade access equipment must be designed for a minimum unfactored live load equal to the larger of the following:

- 2.5 times the rated load of the hoist; and
- 1.0 times the stall load of the hoist.

When multiplied by the live load factor of 1.6, the factored design load becomes the larger of the following:

- 4.0 times the rated load of the hoist; and
- 1.6 times the stall load of the hoist.

These loads match or slightly exceed OSHA's minimum requirements, and they eliminate the need to differentiate between building maintenance loads and construction loads, which is a nebulous distinction at best.

Loads for Components that Support Non-Powered Equipment

OSHA requires that anchorages used to secure non-powered components—like rope descent systems, lifelines, or fall arrest equipment—be able to resist at least 5,000 lbs (2270 kg) per attached worker in any direction of use. In alignment with OSHA, the IBC and ASCE 7-16 both specify an unfactored design live load of 3,100 lbs (1405 kg) for fall arrest anchorages. Multiplying this live load by the 1.6 load factor results in a factored design load of 4,960 lbs (2250 kg), or essentially 5,000 lbs (2270 kg).

Other Design Considerations

Other key considerations to keep in mind when designing façade access equipment are summarized below.

Spacing and Layout of Equipment. Where window washing is performed via rope descent systems, each drop location should have at least two anchorages (one for the descent line and one for the lifeline). The anchorages should be positioned such that the rigging ropes are within 15 degrees of perpendicular to the building edge. Similarly, for access with suspended scaffolding, independent anchorages are required for each worker's lifeline and for any tiebacks of temporary equipment such as counterweighted outrigger beams or parapet clamps. For a 30 ft (9.1 m) long platform used by three workers and suspended from parapet clamps, five anchorages would be required—two

Fig. 2: Davit system and suspended platform (stored on roof)

Fig. 3: Dedicated anchorages for securing lines

tiebacks and three lifelines. Figure 4 shows a conceptual layout for both rope descent and suspended scaffolding. Proper layout of anchorages can be challenging, requiring careful consideration of the activities and equipment involved.

Davit Systems and BMUs. Demands from davit systems and BMUs typically require specifically detailed structural framing. Davits and BMUs support forces similar in magnitude to anchorages, but the moment arm can be much greater, creating large overturning forces that must be resisted by the structural framing. For concrete-framed buildings, while individual lifeline/fall arrest anchorage loads can typically be resisted by a reinforced concrete roof deck, davits and BMUs typically require heavier framing to resist the imposed demands, which can pose significant challenges or make it impractical to retrofit an existing building.

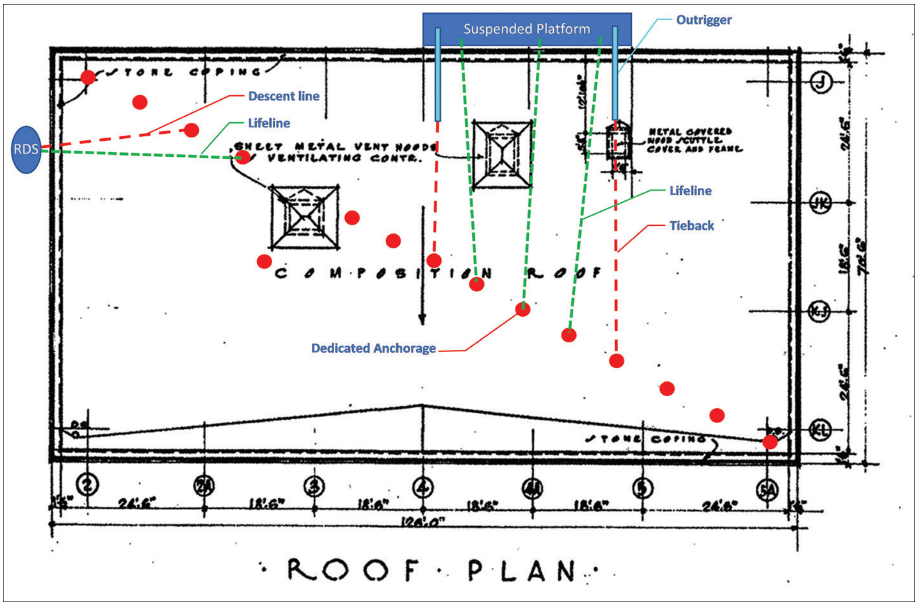

Fig. 4: Sample anchorage layout showing sample rigging configurations

Anchoring to Concrete. Façade access equipment is often secured to concrete framing. For new buildings, cast-in anchors can be incorporated into the original construction. For retrofits of existing buildings, post-installed expansion, adhesive, screw, or undercut anchors are commonly used, especially for installation of discrete anchorage points. When designing anchorage to concrete, use of the provisions of Chapter 17 of ACI 318-19[3] is appropriate. Although Chapter 17 excludes impact, blast, and shock loads, façade access equipment loads are better characterized as live loads with a dynamic component, and therefore fall within the limitations of the Chapter 17 provisions. Most anchor manufacturers are very familiar with façade access applications and can provide recommendations regarding anchors for this equipment, including susceptibility to loosening under cyclic loading. Quality control is also important during installation, and most equipment is subjected to post-installation load testing, which is arguably the strongest form of quality control available if done properly.

TESTING OF FAÇADE ACCESS EQUIPMENT

OSHA Sections 1910.27[4] and 1910.66[5] contain provisions for post-installation certification and testing of façade access equipment, and while the specifics of the "testing" are not defined, most engineers typically rely on some form of in-situ load testing. The test setup and test load are left to the discretion of the engineer, who then uses the test results to certify that the equipment meets the OSHA minimum strength requirements.

Load Testing Controversy

Load testing has long been a valuable tool for determining whether a structural component possesses adequate strength. Alarmingly, some consultants advocate load testing to no more than 50 percent of the required strength and then use the test results to certify that the tested component possesses 100 percent of the required strength. For anchorages, this means testing to 2,500 lbs (1135 kg) and then certifying a strength of 5,000 lbs (2270 kg). For davits, a test load of 2 times the rated load is used to certify a strength of 4 times.

The concept and practice of half-strength testing has proven stubbornly difficult to extinguish, despite the obvious facts that one has never equaled two, two has never equaled four, and 2,500 has never equaled 5,000. In fact, two voluntary industry standards, ANSI/IWCA I-14.1[6], *Window Cleaning Safety Standard* (withdrawn in 2011) and ASME A120.1[7], *Safety Requirements for Powered Platforms and Traveling Ladders and Gantries for Building Maintenance*, actually limit load testing to 50 percent of the required strength. These voluntary standards cannot supersede requirements of mandatory provisions on load testing in standards like the IBC, ACI 318, and ANSI/AISC 360[8], all of which require testing to essentially 100 percent of the required strength, not 50 percent of it.

Some proponents of half-strength testing cite concerns that testing to the required strength could damage the equipment, the supporting structure, or even the waterproofing. There are some equipment designs that must mobilize significant or even excessive levels of inelastic deformations to develop the required strength, and load testing would not be a good choice in these instances. But, in the authors' experience, these situations are rare. In many instances, the concerns regarding damages can be alleviated by simply designing equipment to remain elastic at the required strength.

Risks of Half-Strength Testing

There is zero scientific basis for extrapolating a load test. A weld, an anchor, or a breakout cone that satisfactorily resists 50 percent of the required strength could fail suddenly at, say, 60 percent of the required strength and lead to an accident. As the authors have observed firsthand, testing something to only half of its required strength has the potential to leave a critical defect undetected and expose workers and the public to concealed risk. The folly and danger of half-strength testing should be readily apparent, especially for powered hoists, which can exert stall loads of up to 3 times the rated load, well in excess of 2 times the test value.

Load Testing Best Practices

Proper load testing of any structure or component must verify that the component has at least the required strength. Section 1708 of the IBC governs in-situ load tests and requires testing to at least factored loads, which means either 4.0 times the rated load or 1.6 times the stall load for hoists, and 1.6 times 3,100 lbs (1405 kg) = 4,960 lbs (2250 kg) for anchorages. Testing to lesser amounts violates the IBC and Section 27.4 of ACI 318-19.

Load testing should be performed prior to initial use of the equipment to satisfy requirements in OSHA 1910.27 and 1910.66, after any major modification to the equipment, and after any damage has occurred. While not specifically mandated, common industry practice (differences on load magnitude notwithstanding) is to re-test every 10 years to catch any damage or gradual deterioration that could be concealed.

It is also important to load test components in the actual direction(s) they are loaded during use, particularly toward the edge of the roof. Wherever possible, deflection of the tested component should be monitored during the test. It is good practice to apply the required load at least twice, comparing deflections at each peak. If the deflections are essentially equal, there is good confidence that the component is behaving elastically and is fit for service. Figures 5 through 7 show some common load testing setups.

CONCLUSIONS

Façade access equipment plays a critical role in facilitating safe and efficient maintenance and construction on building façades. Proper design and testing of this equipment improves worker and public safety. Structural engineers have benefited from recent updates to the IBC and ASCE/SEI 7 that clarify façade access equipment loads and harmonize these loads with other loads commonly encountered in the design of roof structures. Although there is still some misunderstanding in the industry regarding test loads, the IBC, ACI 318, and ANSI/AISC 360 are clear: in-situ load testing must be conducted to the factored loads, and not half these loads. Failure to test to the proper loads conceals risk from the equipment users and the general public.

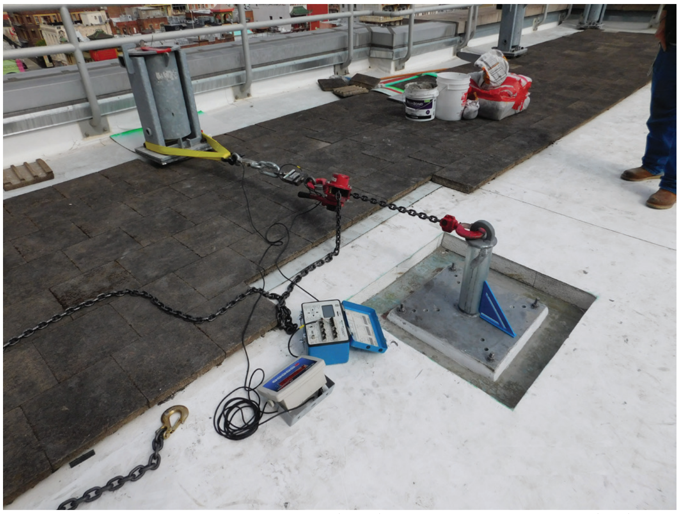

Fig. 5: Load test of fall arrest anchorage (right) reacting off a davit base (left)

Fig. 6: Load test of davit pedestal replicating overturning moment generated during use

Fig. 7: Load test of davit socket replicating overturning moment generated during use

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