

Fixed Ladder Systems: Improvement Proposal based on OSHA Compliance Findings

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Abstract — *Fixed ladders are critical access systems in industrial facilities, and deficiencies in their design, condition, and fall protection features pose significant safety and regulatory risks. This design project evaluated the compliance of external fixed ladders at a biotechnology facility with applicable Occupational Safety and Health Administration (OSHA) requirements. Nineteen fixed ladders were assessed through field inspections, dimensional measurements, photographic documentation, and structured comparison against OSHA fixed ladder and personal fall arrest standards. The evaluation identified widespread partial compliance, with recurring deficiencies related to ladder clearances, rung surface conditions, corrosion, and fall protection provisions. An internal fall protection benchmark of 16 ft was adopted to enhance worker safety based on existing site conditions and engineering judgment. Targeted engineering controls were proposed, including ladder replacement, dimensional modifications, installation of personal fall arrest systems, removal of obsolete ladder cages, and improvements to access geometry. The project produced a contractor-ready scope of work supported by ladder-specific compliance data and site-specific recommendations, demonstrating the value of systematic ladder compliance assessments for improving occupational safety in industrial environments.*

Key Terms — *Fixed Ladders; Fall Protection; OSHA Compliance; Personal Fall Arrest Systems.*

PROBLEM STATEMENT

Fixed ladders are essential infrastructure components that provide routine access to elevated

platforms, rooftops, and utility areas within industrial facilities. Although these assets are often located outside of direct manufacturing spaces, as is the case for this design project, they remain critical elements of safe site access and must comply with OSHA requirements. During an internal audit, my organization's Environmental Health and Safety (EHS) department identified potential compliance gaps in several external ladder systems. The EHS department assessment mainly focused on travel restraint systems and cage systems. Cages were a main concern since they are no longer considered a fall arrest system for new fixed ladders under OSHA 1910.28 (b)(9)(i)(B) and, in ladders over 24', need to be supplemented by a fall arrest system or ladder safety system in existing ladders, as per OSHA 1910.28. (b)(9)(i)(D). After the assessment, the EHS department coordinated efforts with the Project Engineering department to address concerns. The project engineering team, of which I was a part, went a step further and conducted a comprehensive evaluation of the 19 fixed ladders mentioned in the EHS assessment. This revealed additional design deficiencies and highlighted opportunities to exceed regulatory minimums. The need to systematically evaluate ladder conditions, benchmark against OSHA standards, and propose corrective modifications formed the basis of this design project.

RESEARCH DESCRIPTION

This research focuses on a systematic assessment of fixed ladder systems located in external and support utility areas of a biotech facility. The study involved field inspections, measurement of critical ladder dimensions, documentation of physical conditions, and

comparison against OSHA standards and current fall protection best practices. The ladders evaluated during this assessment serve operational infrastructure and are not directly tied to GMP-regulated manufacturing processes. The work culminated in the development of a design improvement proposal detailing required corrections, recommended ladder replacements, fall-arrest installations, and removal of caged systems. The final step of the project involved walkthroughs with external contractors to obtain modification cost estimates (confidential to the organization).

using site blueprints. Subsequent phases focused on consolidating inspection data, evaluating compliance against regulatory criteria, and identifying deficiencies and improvement opportunities. The final phase involved engineering decision-making, contractor walkthroughs, development of a contractor-ready scope of work, and preparation of project results and conclusions. The overall timeline and task sequencing are summarized in the Gantt chart presented in **Figure 1**, which illustrates the duration and overlap of major project activities.

RESEARCH TIMELINE

The design project was conducted over a four-week period, from October 20 to November 14, 2025, following a structured full-time schedule. The timeline was organized to reflect the sequential and iterative nature of the work, progressing from project scoping and regulatory review to field assessment, technical evaluation, and final documentation. During the initial phase, applicable OSHA fixed ladder and fall protection requirements were reviewed. This was followed by on-site ladder inspections, dimensional measurements, photographic documentation, and spatial mapping

RESEARCH CONTRIBUTIONS

This project contributes the following to the organization and to the field of industrial safety design: 1) A comprehensive compliance assessment of external fixed ladders, consolidating all ladder conditions and deficiencies into a single structured analysis; 2) a decision-making framework for determining when fall-arrest systems, ladder replacement, or structural modifications are required; 3) a design improvement proposal that exceeds minimum regulatory requirements through the application of a conservative fall protection benchmark; 4) a replicable methodology that can be applied to future infrastructure assessments.

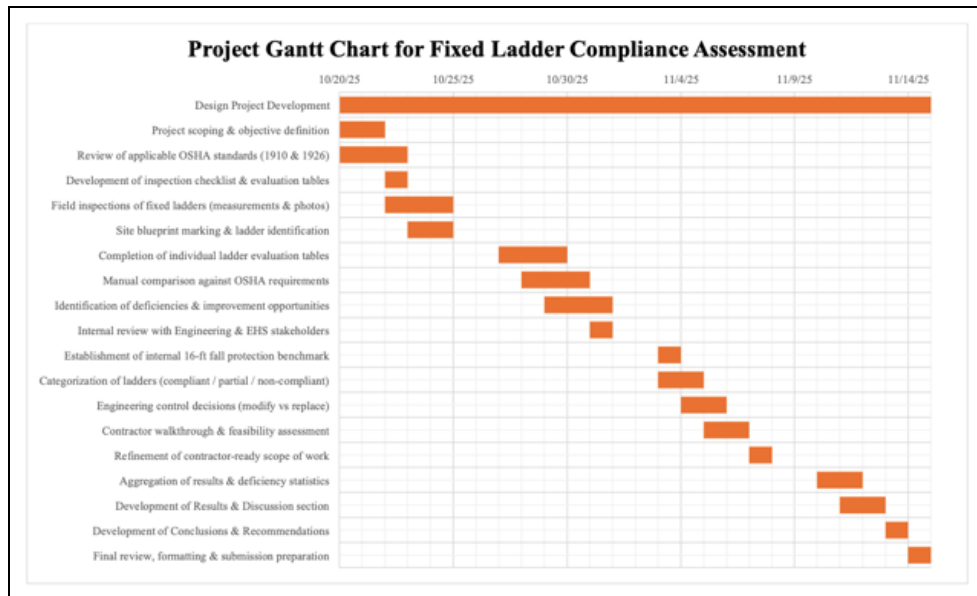


Figure 1
Project Gantt Chart: October/November 2024

LITERATURE REVIEW

Fixed ladders are controlled access systems in industrial settings, and their proper design and maintenance are regulated by OSHA to ensure operator safety. Falls continue to be one of the leading occupational hazards in the United States [1], making ladder compliance a vital part of workplace safety programs. OSHA standard 29 CFR 1910.23 provides technical requirements for the design, construction, and use of ladders in general industry [2]. For fixed ladders, this includes dimensional specifications such as rung spacing, rung design (minimum diameter, required texture or shape for secure footing), side rail clearance requirements, minimum perpendicular clearance from the climbing surface to the nearest obstruction, requirements for landing platforms and step-across distances, and others [2]. Section 1910.23 further prohibits design conditions that create entanglement or fall hazards, such as protruding components [2]. These specifications relate to several deficiencies identified in the facility under study, including smooth rungs, slippery surfaces, protruding grab bars, and non-compliant clearances.

OSHA 29 CFR 1910.28 establishes when employers must provide fall protection systems [3]. Section 1910.28(b)(9)(i)(D) establishes that fixed ladders over 24 feet (installed after November 19, 2018) must be equipped with a personal fall arrest system (PFAS) or a ladder safety system. For older ladders, cages and wells (previously accepted for fall protection) are being phased out under the transition timeline outlined in this standard; as of 2018, OSHA no longer recognizes cages alone as an adequate fall-arrest mechanism [3]. The phasing-out of ladder cages has shifted industry emphasis toward engineered fall-arrest systems that offer superior control; studies within occupational safety engineering highlight the importance of engineering controls in conjunction with existing administrative controls [4].

OSHA 29 CFR 1910.29 specifies performance criteria for fall protection systems, details minimum

strength requirements and installation parameters necessary to ensure fall-arrest functionality; additionally, Section 1910.29 (g) details cage specifications, which were evaluated during the study [5]. On the other hand, 29 CFR 1926.1053, which applies to construction, provides complementary guidance relevant to temporary access and ladder modification work [6]. Since the modification of fixed ladders and the installation of fall protection systems involve work performed under construction contexts (i.e., scaffolding), this standard is useful for ensuring the safe execution of redesign activities. This standard also serves to reinforce principles found in 1910.23, such as PFAS for climbs exceeding 24' [6].

National labor data show that the rate of fatal and nonfatal incidents in construction has remained persistently high, demonstrating that falls continue to be a major safety challenge: falls account for over 40% of fatal injuries in the U.S. construction industry [7]. Providing adequate fall protection before work begins is identified as the most effective strategy to reduce fall risk; additionally, no single fall-protection method addresses all hazards; therefore, a comprehensive, site-specific fall protection plan is necessary to mitigate diverse risks [7].

METHODOLOGY

This design project employed a field-based assessment methodology to evaluate the compliance of external fixed ladders with applicable OSHA standards and to develop recommendations for improvement. The methodology consisted of systematic data collection, dimensional measurement, regulatory comparison, contractor engagement, and collaborative analysis to determine appropriate corrective actions.

A total of 19 fixed ladders were assessed through on-site inspections conducted using a tape measure, visual inspection, photo documentation, and a standardized OSHA-based checklist. Each ladder was individually evaluated in its installed

environment to capture dimensional, structural, and situational factors influencing compliance and safety. A custom evaluation table was developed for each ladder to ensure consistency across assessments. The inspection criteria were derived directly from OSHA 29 CFR 1910.23 and included, but were not limited to the parameters described on **Table 1**.

Table 1
Fixed Ladder Systems Assessment Parameters

Table 1: Fixed Ladder Systems Assessment Parameters	
1	spacing and width of rungs
2	perpendicular clearance and side clearances to permanent structures
3	step-across distance at access points
4	side rail extensions and flaring at access levels
5	presence and configuration of grab bars
6	surface conditions and slip resistance
7	ladder pitch and total ladder height
8	fall protection requirements
9	clearance and access considerations for hatch ladders

Each criterion was marked as compliant, non-compliant, or opportunity for improvement, and ladder-specific observations were recorded in a comments field to capture contextual details not reflected by measurements alone.

Before my involvement in the project, each ladder had been uniquely identified using the organization’s internal labeling system and documented individually. Using this nomenclature enabled traceability and clear communication among engineering, EHS, and contractors. Ladders were referenced by both numerical identifier and physical location (e.g., rooftop access, waste pit, external yard); additionally, each evaluated ladder

was mapped and labeled on a blueprint of the site. Photographic documentation was collected when necessary to visually support observations made during the evaluations.

All dimensional measurements were taken manually and compared directly against OSHA requirements. Compliance determinations were made through manual comparison with OSHA standards rather than automated tools, allowing for engineering judgment when interpreting borderline conditions. Material condition was also evaluated during inspections. Evidence of corrosion, structural degradation, or compromised integrity was documented and incorporated into the decision-making process. In cases where ladder deterioration was significant, contractor input was incorporated to validate replacement recommendations.

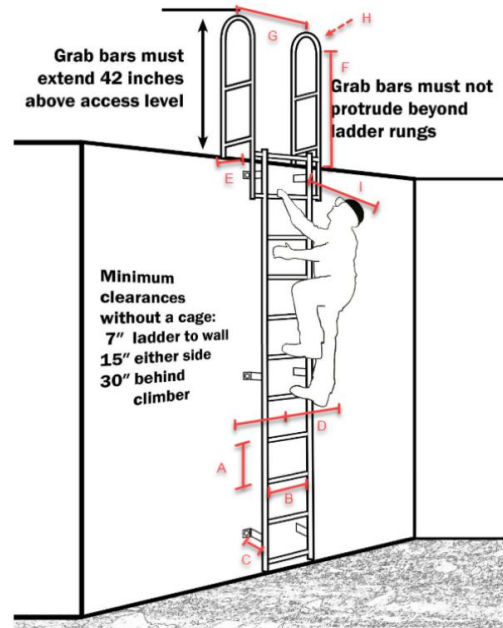


Figure 2

Image Courtesy of Charles Brown of the University of Florida [8]. Highlighted in red are the dimensions under evaluation by the engineering department.

Although OSHA establishes a 24-foot threshold for mandatory fall protection on fixed ladders, this project suggested a more conservative 16-foot internal benchmark. This threshold was selected based on the shortest ladder already equipped with a personal fall arrest system (PFAS)

within the facility and was formally agreed upon by the engineering team. All existing ladder cages were designated for at least a modification in which the cage component would be removed.

Following completion of the internal evaluations, a guided walkthrough was conducted with a qualified contractor. During this walkthrough, each ladder's condition, location, and proposed corrective action were reviewed. Contractor input was used to assess feasibility, constructability, and whether modification or full replacement was the most appropriate solution. Supporting materials provided to the contractor included: a ladder dimension reference diagram (shown below in **Figure 2**); individual evaluation tables for each ladder; site blueprint with each ladder's location; and photographic documentation where necessary.

Modification was recommended when ladders were structurally sound and required limited changes such as anti-slip treatment, repainting, or repositioning to achieve clearance compliance. Replacement was recommended when ladder geometry (e.g., rung width) was non-compliant or corrosion compromised structural integrity. Fall protection systems and pick points were required for ladders exceeding 24 feet and recommended for those exceeding the 16-foot internal benchmark. Clearance geometry adjustments were tailored to each ladder's environment, including ladder rotation, lateral relocation, or installation of deflection plates for hatch ladders. Prioritization focused on OSHA compliance and contractor safety during implementation, rather than cost or usage frequency.

Data collection and analysis were supported using Microsoft Excel for tabulation and a digital camera for photographic records. OSHA standards were the sole regulatory references used in this project. The primary outputs of the methodology included a consolidated deficiency list, ladder-

specific modification and replacement recommendations, and a contractor-ready scope of work to support implementation planning.

RESULTS AND DISCUSSION

A total of 19 fixed ladders were evaluated:

- 1 ladder was found to be fully compliant with all evaluated criteria.
- 11 ladders were classified as partially compliant, meeting at least 8 of the 15 evaluated criteria.
- 7 ladders were classified as non-compliant due to major deficiencies, including excessive pitch ($>90^\circ$), lack of required fall protection, or significant corrosion.
- 6 ladders were recommended for full replacement:
 - 1 ladder due to non-compliant pitch and rung width (Ladder #24),
 - 5 ladders due to extensive corrosion in high-traffic areas (Ladders #40, #45, #46, #47, and #48).
- 13 ladders were recommended for modification rather than replacement.
- 5 ladders required personal fall arrest systems (PFAS):
 - 2 ladders already equipped,
 - 1 ladder required PFAS per OSHA (≥ 24 ft),
 - 2 ladders recommended per the internal 16-foot benchmark.
- 8 existing ladder cages were identified, and their modifications include the removal of the cages.
- Scaffold access will be required at 10 locations to safely execute the proposed modifications.
- Replacement of swing gates is recommended for 5 ladders.

A consolidated recollection of the aggregated deficiency counts is provided in **Table 2**.

**Table 2
Aggregated Deficiency Counts**

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Compliance criterion	Non-Compliant Ladders per OSHA	Could be improved
Spacing Between Rungs	0	0
Width of Rungs	1	0
Perpendicular Clearance Behind Ladder	5	0
Width to nearest permanent object (sides)	5	0
Step-across Distance to access point	12	0
Side Rail Extensions over access level	3	0
Side Rail Flaring	3	0
Grab Bars present, extend 42" above access level and must not protrude	8	2
Perpendicular Clearance on the Climbing Side	2	0
Non-Slippery Rung Surface or Textured Rungs	16	3
PFAS when required	1	2
Pitch	1	0
Steps Omitted from access point	0	0
Hatch Ladder Clearances	0	0
Openings over 4' (Travel Restraint System)	7	0

Compliance Findings by Evaluation Criterion

The aggregated results revealed that full compliance across all evaluated criteria was uncommon, with deficiencies concentrated in ladder geometry, surface conditions, access transitions, and fall protection provisions. The most prevalent non-compliances were associated with slip resistance and rung surface conditions, where 16 of the 19 ladders lacked non-slip or textured rungs. In addition, step-across distance non-compliance was identified in 12 ladders, indicating widespread access transition risks at ladder entry and exit points. In most cases, step across distance non-compliance was due to the distance being shorter than 7 inches which is the required minimum as per OSHA 1910.23(d)(12)(i). Clearance-related deficiencies were also common.

Five ladders failed to meet minimum perpendicular clearance behind the ladder, while another five ladders did not meet side clearance requirements to the nearest permanent object. Eight ladders lacked compliant grab bars extending 42 inches above the access level or had protruding configurations that posed potential entanglement hazards.

Fall protection gaps were observed as well. Seven ladders associated with openings greater than four feet either required swing gate replacement or lacked travel restraint systems; additionally, one ladder exceeded OSHA’s 24-foot threshold without a personal fall arrest system (PFAS). Eight ladders were equipped with cages, which are no longer recognized as compliant fall protection systems and were therefore designated for modification, in which the cage element is to be removed.

Isolated but critical deficiencies were identified in ladder pitch and rung width. One ladder exceeded acceptable pitch limits, and this same ladder failed rung width requirements; these conditions warranted full replacement for the ladder (Ladder #24).

Conditions Identified for Improvement

In addition to non-compliant conditions, several ladders met minimum OSHA requirements but were identified as candidates for safety enhancement beyond regulatory minimums. Three ladders were equipped with textured rungs but were recommended for the addition of sand-based anti-slip treatment to further reduce slip risk, particularly in external environments. Two hatch ladders were compliant but lacked dedicated hatch ladder grab posts, which were recommended to improve safe transitions at roof access points. Two ladders exceeding 16 feet in height, though compliant with OSHA thresholds, were recommended for PFAS installation based on the project’s conservative internal benchmark.

Prevalence and Nature of Deficiencies

The results indicate that the majority of ladder deficiencies were systemic rather than isolated, particularly in areas related to surface conditions,

access transitions, and clearance geometry. The high frequency of non-slip surface deficiencies suggests that environmental exposure plays a significant role in degrading ladder safety over time, especially for external ladders present in a tropical environment.

Clearance and step-across deficiencies further demonstrate that ladder installations often meet structural needs but periodic subsequent evaluations are necessary to keep up with the adapting environment; in some cases, obstructions identified were elements that came after ladder installation, and the ladders were not modified accordingly.

Fall Protection Strategy and Conservative Benchmarking

While OSHA requires fall protection for fixed ladders exceeding 24 feet, this project intentionally adopted a 16-foot internal benchmark. This decision was informed by existing site conditions and engineering judgment and resulted in two additional ladders being flagged for pick point and PFAS installation beyond regulatory requirements. This approach aligns with that of other effective safety programs, where proactive measures are just as important as reactive measures to reduce risk exposure [9]. The identification and removal of eight ladder cages further reflects the shift away from legacy fall protection systems toward modern ladder safety systems.

Engineering Controls and Decision-Making

The distinction between modification versus replacement was guided by structural condition, dimensional compliance, and feasibility. Ladders exhibiting excessive corrosion in high-traffic areas or fundamental dimensional non-compliance were designated for replacement, while structurally sound ladders were targeted for modification through anti-slip treatments, clearance adjustments, or repositioning. The need for scaffold access at 10 locations highlights the complexity of implementing ladder modifications safely and reinforces the importance of contractor safety during corrective work.

Implications for Industrial Safety Management

Although the evaluated ladders serve external and non-GMP areas, the findings demonstrate that support infrastructure represents a significant safety exposure when not systematically assessed. By consolidating ladder deficiencies into a single evaluation framework, this project provides a repeatable methodology that can be applied to future facility assessments and capital planning efforts.

CONCLUSION

The problem of unknown and inconsistent OSHA compliance among external fixed ladders at the site was resolved through a systematic, ladder-by-ladder field evaluation aligned with applicable OSHA standards. As demonstrated by the data, only one of the nineteen ladders evaluated was fully compliant, confirming the necessity of a structured compliance assessment rather than reliance on assumed conformity. Non-compliance was predominantly driven by access geometry, surface conditions, and fall protection gaps rather than isolated defects. The most frequent deficiencies involved non-slip rung surfaces, step-across distances, clearance constraints, and outdated ladder cage systems, indicating systemic design and aging infrastructure issues rather than improper use. Furthermore, the application of a conservative 16-foot internal fall protection benchmark led to the proactive identification of additional ladders recommended for PFAS installation, which may lead to safer operating conditions.

Limitations

The scope of this study was limited to external fixed ladders within a single industrial facility, and therefore the results may not be directly generalizable to internal ladders or facilities with different environmental, operational, or structural conditions. Only OSHA regulations were used as evaluation criteria, excluding standards such as ANSI A14, which may recommend more stringent requirements. Lastly, the assessment focused on

physical ladder conditions and configurations, and did not include behavioral factors such as user training, frequency of ladder use, or incident history, which may further influence overall fall risk.

Contributions

Through this design project, I was able to develop a structured OSHA-based evaluation methodology for assessing fixed ladder compliance, incorporating dimensional measurements, clearance analysis, surface condition assessment, and fall protection requirements. The assessment produced a contractor-ready scope of work that translated regulatory deficiencies into actionable engineering controls, including ladder modifications, replacements, fall protection installations, and clearance geometry corrections. Additionally, this project explored the value of adopting internal safety benchmarks that exceed regulatory minimums as a means of proactive risk reduction in industrial ladder systems.

Future Research

This project lends itself to growth in the following areas:

- Expansion of the evaluation framework to include ANSI and NIOSH guidance to further strengthen ladder safety programs.
- Quantitative risk prioritization models, incorporating ladder usage frequency, environmental exposure, and worker task duration, could enhance decision-making when allocating capital for ladder upgrades.
- Longitudinal studies assessing post-modification incident rates and near-miss data would provide valuable insight into the effectiveness of engineering controls implemented as a result of this project.

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