Design of Commercial - Industrial Guardrail Systems for Fall Protection

An Online Continuing Education Course for Engineers

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Design of Commercial / Industrial Guardrail Systems for Fall Protection

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1.0 Introduction

Falls are among the most common causes of serious work related injuries and deaths. Employers are required to provide and install fall protection systems to prevent employees from falling off of overhead platforms and elevated work stations or into holes in the floor. Falls can be prevented through the use of proper fall protection systems, such as guardrail systems, safety net systems, and personal fall arrest systems, and positioning device systems. Fall protection systems are an expansive topic, and this course will focus solely on guardrail systems.

Whether in construction or general industry, a structural engineer may be called upon to design a new guardrail system or to evaluate the adequacy of an existing guardrail system in accordance with the Codes of the local jurisdiction. The design of a simple guardrail system has become more complicated as there is no single guardrail design that will work for all situations. There are different functional Code requirements depending upon the local jurisdiction and the design engineer must interpret the latest version of these regulations and Codes and apply them to specific applications.

This course provides a procedure for designing or evaluating guardrail systems in commercial / industrial applications. A number of published methods, tables and charts from industry manuals, manufacturer's engineering data, and Codes provide a good source of design information and criteria for guardrail systems. It is not the intent of this course to duplicate this information but rather to extract appropriate data from these documents as well as provide direction regarding the proper use or application of such data so that engineers and designers involved in preparing the calculations can make the appropriate decision and/or apply proper engineering judgment. Also, since Codes change periodically and requirements may vary by jurisdiction, the engineer should consult the latest Code versions when designing guardrail systems.

This course includes a design example for better understanding of the subject matter.

2.0 Glossary of Terms

Commonly used terms relative to guardrail systems in this course are defined below in accordance with American Society of Testing and Materials *Standard Terminology of Railing Systems and Rails for Buildings* (ASTM E 1481), and National Association of Architectural Metal Manufacturers, *Pipe Railing Systems Manual including Round Tube* (NAAMM AMP 521-01).

ANCHOR — Any device used to secure a railing system or its parts to adjoining construction or a supporting member.

FASCIA — The exposed facing of the outer edge of a platform or floor.

FASTENER — A mechanical device that holds or joins two or more components in definite positions with respect to each other and is often described as a bolt, nut, rivet, screw, washer, or special formed part.

GUARDRAIL SYSTEM — A railing system, providing protection for building users against accidental fall and injury, located at or near the outer edge of a stair, ramp, landing platform, deck, balcony, hatchway, manhole, floor opening, porch, or accessible roof; at the perimeter of an opening or accessible surface, such as the opening of a stair; or at a location at which an operating condition requires access limitation to a designated area.

INTERMEDIATE RAIL — One of two or more rails between the top rail and floor.

MID RAIL — A rail located between the top rail and bottom rail or between top rail and floor if there is no intermediate rail.

PIPE — Hollow round section of metal or other material, the size of which is usually designated by nominal size, in inches (millimeters), as influenced by inside diameter and wall thickness.

POST — A vertical supporting member.

RAIL — A horizontal, inclined, or vertical member of a railing system, such as top or intermediate member connecting posts at specified intervals.

TOE BOARD — A vertical plate at the bottom of a railing system.

TOP RAIL — The uppermost member of railing system.

TUBE / TUBING — Hollow section of metal other material having a round, square, rectangular, or other cross-sectional form, its size being designated by outside dimension(s) and wall thickness, in inches (millimeters).

3.0 General Design

The availability of complete structural information enables architects and engineers to properly design guardrail systems. The systems can then be designed to conform to specific building code criteria.

In the structural design of any guardrail system, the following information is essential:

1. The design criteria, as prescribed by governing regulations or the designer's specifications.
2. Mechanical and physical properties of guardrail components.
3. Formulas for structural design.
4. Anchoring systems.

3.1 Design Criteria

Design criteria for railing systems are set by the governing code for the area in which the railing systems are to be used. These criteria include both loading and dimensional requirements. The designer should consult governing codes, local ordinances, project specifications, and regulatory authorities to determine requirements for compliance.

For guardrail systems, local codes generally follow the requirements established by the International Building Code (IBC) and/or the Occupational Safety and Health Administration (OSHA).

Guardrail requirements are outlined in IBC Section 1013 (Guards) and Section 1607.8 (Loads on Handrails, Guards, Grab Bars, Seats and Vehicle Barriers).

OSHA fall protection requirements for general industry and construction are addressed in 29 CFR 1910.23 and 29 CFR 1926 Subpart M, respectively, in the Code of Federal Regulations.

Governing codes shall be checked for their specific requirements, and government regulations, such Americans with Disabilities Act (ADA), shall be checked as well. In certain instances, exterior guardrails shall also be designed for wind loads calculated in accordance with the local Building Code. This typically pertains to guardrail systems with picket, perforated, wire mesh, or glass infill panels, which are located between the posts and are supported by the top and bottom rails.

3.1.1 Loading Requirements

Uniform loading, specified by some building codes, represents the force exerted by tightly grouped persons leaning on or pressing against the railing system. Such loading requirements range from 20 to 50 pounds per foot applied to the top rail depending upon the area occupancy load.

Concentrated loading represents the force exerted by a single individual leaning upon or over the rail or a person or object impacting upon the rail. A 200 pound concentrated load applied in any direction at any point along the top rail has become a requirement of a number of codes and government regulatory agencies. Current thinking by some organizations is to apply the concentrated load in a perpendicular direction at any point along the top rail, horizontally and downward in a vertical plane, but not simultaneously. Perpendicular horizontal loading applies the maximum

moment to the post, and the downward loading simulates what a person leaning over the rail might apply.

3.1.2 Guardrail Height and Spacing

Building codes typically specify minimum and maximum heights for handrails and minimum spacing for intermediate rails. The minimum guardrail system height requirement of the majority of codes is 42 inches plus or minus 3 inches.

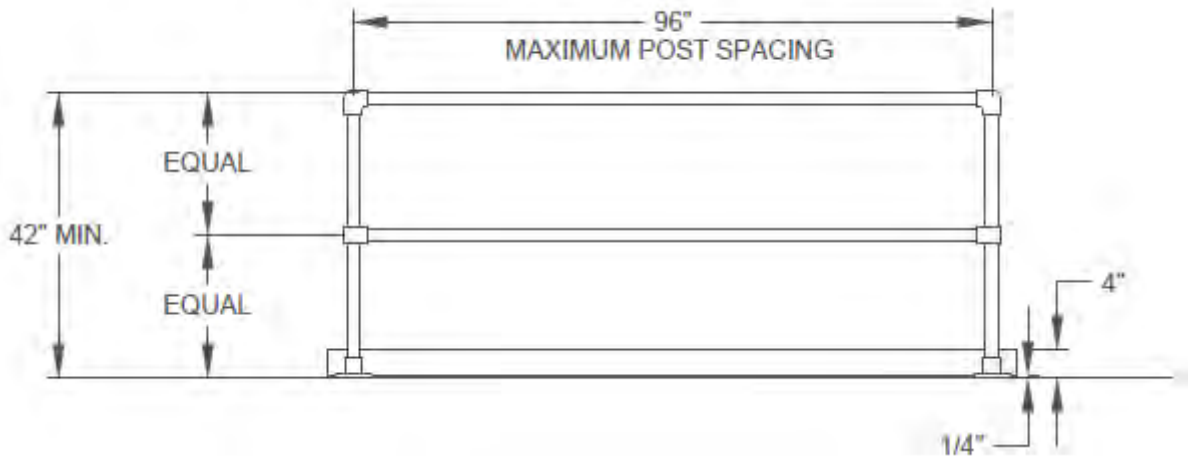
OSHA has a requirement that hand rails, posts, and top and intermediate rails shall be at least 1-1/2 inch nominal diameter, with posts spaced not more than 8 feet on centers.

For guardrail systems and stair-rail systems in areas accessible to the public, codes require spacing, between rails, balusters or other infill, small enough to prevent the passage of a sphere of diameter varying between 4 inches and 6 inches. In areas of commercial and industrial occupancies, which are not accessible to the public, some codes permit this spacing to be increased to prevent passage of a 21 inch diameter sphere.

3.1.3 Code Illustrations

Illustrations of the OSHA and IBC code and loading requirements are provided in **Figures 1 and 2**, respectively. All codes shown in these illustrations are interpretations. The Engineer should consult local codes, since many municipalities use variations of these codes and the codes change continuously.

Figure 1 – OSHA Requirements



Selected Code Requirements:

OSHA - General Industry

29 CFR 1910.23(e)(1) – A standard railing shall consist of a top rail, intermediate rail, and posts, and shall have a vertical height of 42 inches nominal from upper surface of top rail to floor, platform, runway, or ramp level. The intermediate railing shall be approximately halfway between the top rail and the floor, platform, runway, or ramp.

29 CFR 1910.23(e)(3)(ii) – For pipe railings, posts, and top and intermediate railings shall be at least 1-1/2 inches nominal diameter with posts spaced not more th on centers.

29 CFR 1910.23(e)(3)(iv) T embers for railings of all types shall be of such co le of withstanding a load of at least 200 pounds ap

29 CFR 1910.23(e)(n vertical height from its top edge to the level of curely fastened in place and with not more than ½

OSHA - Construction

29 CFR 1926.502(b)(es plus or minus 3 inches above the walking / w

29 CFR 1926.502(b)(2 between the top edge of the guardrail system an

29 CFR 1926.502(b)(3) without failure, a force of at least 200 pounds a ard or downward direction, at any point along the to

29 1926.502(j)(3) – Toeboards shall be a minimum of 3-1/2 inches in vertical height from their top edge to the level of the walking/working surface. They shall have not more than ¼ inch clearance above the walking/working surface. They shall be solid or have openings not over 1 inch in greatest dimension.

29 CFR Part 1926 Subpart M Appendix B – For pipe railings: posts, top rails, and intermediate railings shall be at least one and one-half inches nominal diameter (schedule 40 pipe) with posts spaced not more than 8 feet apart on centers.