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Comparación de normativas sobre la prevención del riesgo de caídas en los cambios de nivel entre Estados Unidos y España
Comparison of regulations regarding fall risk prevention on level changes between the United States and Spain

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Resumen-- **Las caídas desde altura durante la construcción son la principal causa de accidentes graves y mortales en el sector de la construcción y en la industria en general. Durante las fases de uso y mantenimiento de los edificios, este tipo de accidente también provoca una alta incidencia de lesiones. El sistema más utilizado para prevenir estos riesgos es la instalación de barandillas de seguridad. Centrados en la prevención de riesgos de caídas en edificios durante sus etapas de uso y mantenimiento, para que las barandillas de protección cumplan eficazmente su función protectora, deben cumplir un conjunto de requisitos geométricos y mecánicos. Estas incluyen asegurar que sus dimensiones eviten que las personas los pasen por alto y que los sistemas sean suficientemente resistentes para soportar la fuerza ejercida por inclinarse o impactar a individuos u objetos. Este estudio compara las normas regulatorias utilizadas en Estados Unidos (IBC y OSHA) y en España (CTE) respecto a las barreras de protección destinadas a prevenir caídas en edificios durante sus fases de uso y mantenimiento. Los resultados revelan diferencias significativas en los requisitos impuestos por cada país, mostrando que para las barreras de seguridad con un espaciamiento entre postes inferior a 2,44 metros, las normativas estadounidenses son más estrictas que las de España**

Palabras clave— Riesgo de caídas; gradiente; CTE; IBC; OSHA.

Abstract— **Falls from height during building construction are the leading cause of serious and fatal accidents in the construction sector and industry at large. During the usage and maintenance phases of buildings, this type of accident also results in a high incidence of injuries. The most used system to prevent such risks is the installation of safety guardrails.**

Focusing on the prevention of fall risks in buildings during their usage and maintenance stages, in order for guardrails to effectively serve their protective function, they must meet a set of geometric and mechanical requirements. These include ensuring that their dimensions prevent individuals from bypassing them and that the systems are sufficiently resistant to withstand the force exerted by leaning or impacting individuals or objects.

This study compares the regulatory standards used in the United States (IBC and OSHA) and in Spain (CTE) concerning guardrails intended to prevent falls in buildings during their usage and maintenance phases.

The results reveal significant differences in the requirements imposed by each country, showing that for guardrails with a post spacing of less than 2.44 meters, U.S. regulations are more stringent than those of Spain

Index Terms— Risk of falls; gradient; CTE; IBC; OSHA.

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I. Introduction

Falls from height are among the leading causes of serious and fatal accidents related to buildings, both during construction and in their usage and maintenance stages.

In the construction stage, the Occupational Safety and Health Administration (OSHA, 2015) and the Bureau of Labor Statistics (2019) confirm, based on statistics, that falls from height are the main cause of fatal accidents in a sector that in the United States accounts for approximately one-third of all industrial fatalities. The prevention of this risk is usually addressed through temporary guardrails regulated in the U.S. by OSHA (2016) and in Spain and Europe by the European Committee for Standardization (2019). González et al. (2011) have studied the behavior of steel systems under static loads, impact loads (2012), and the relationship between both load types (2015).

The fall risk during the usage and maintenance phases of buildings necessitates the installation of permanent guardrails, regulated in the U.S. mainly by the International Code Council (ICC) via the International Building Code (IBC, 2024), and in Spain by the Technical Building Code (CTE, 2008).

These documents specify both geometric and mechanical requirements to ensure that guardrails effectively protect users during building use or maintenance. However, despite the shared objective, the mechanical requirements differ substantially when comparing the IBC and CTE.

This paper aims to compare and analyze the geometric and mechanical differences in the guardrail standards of the United States and Spain, identifying the practical implications for safety in buildings during their use and maintenance stages. To achieve this goal, the paper first analyzes the requirements established in Spain and the United States for guardrail design; second, it compares the requirements of both countries; and finally, it evaluates a practical case to illustrate the results obtained under both regulatory systems..

II. DESIGN OF PERMANENT GUARDRAILS IN SPAIN

T In Spain, the mandatory regulation governing permanently installed building guardrails for fall risk protection is the Technical Building Code (CTE).

The CTE is structured into 11 documents. The relevant document for defining the characteristics of guardrails to prevent fall risks is the Basic Document SUA – Safety of Use and Accessibility (DB SUA), issued by the Ministry of Transport, Mobility and Urban Agenda (2022). The purpose of this document is to reduce to acceptable levels the risk of users suffering harm during the intended use of buildings due to their design, construction, use, and maintenance. It comprises nine basic requirements: SUA 1 to SUA 9. Basic Requirement SUA 1, Safety Against Fall Risk, sets the criteria for minimizing the risk of users falling due to slipping or falling through voids, level changes, stairs, and ramps.

Section 3, titled Level Changes, specifically addresses permanent guardrail protection.

Firstly, it specifies when protective measures are required. Barriers must be installed in areas with level differences, voids, and openings (both horizontal and vertical), balconies, windows, etc., when the height difference exceeds 55 cm, except when the construction layout makes falling highly unlikely or when a barrier is incompatible with the intended use.

Additionally, in public use areas, level differences not exceeding 55 cm that may cause falls must be made perceptible through visual and tactile differentiation. The differentiation must begin at least 25 cm from the edge.

Secondly, it outlines the characteristics that protective barriers must meet. These are divided into geometric characteristics—primarily minimum height—and mechanical characteristics—required strength.

For geometric characteristics, the regulation specifies that the minimum height of protective barriers must be 0.90 m when the height difference is ≤6 m, and 1.10 m otherwise, except for stair voids narrower than 40 cm, where the minimum height is also 0.90 m (Fig. 1.).

The height is measured vertically from the floor level or, in the case of stairs, from the slope line defined by the stair tread vertices up to the upper edge of the barrier (Fig. 2).

Protective barriers, including those on stairs and ramps in residential buildings or nurseries, and in public areas of commercial or public-use buildings, must be designed to:

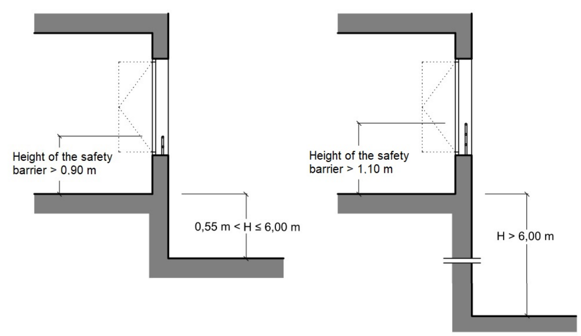

Fig. 1. Height of the protective railing depending on the height difference to be protected (DB SUA).

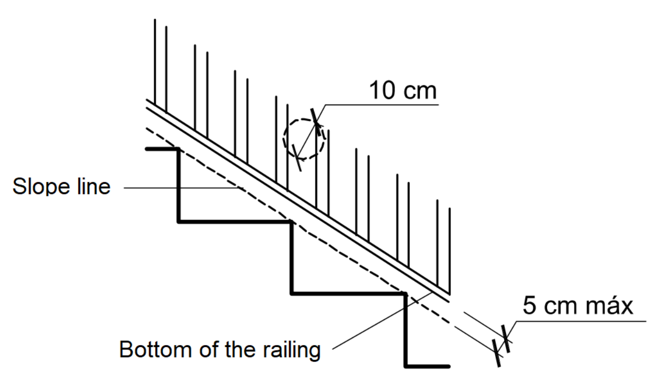

Fig. 2. Measurement of the height of the protective railing on stairs (DB SUA)

- Prevent easy climbing by children.
  - Between 30 cm and 50 cm above floor level or stair slope line, no footholds or substantially horizontal protrusions >5 cm are allowed.

  - Between 50 cm and 80 cm above the floor, no protrusions >15 cm deep with horizontal surfaces are allowed.
- Openings must not allow the passage of a 10 cm diameter sphere, except for triangular openings formed between stair treads and the lower edge of the guardrail, provided the gap between this edge and the stair slope line is ≤5 cm. (Fig. 2).

For public-use areas in buildings not mentioned above, only the last condition applies, with a 15 cm sphere limit.

Regarding mechanical characteristics, DB SUA states that protective barriers must have adequate strength and stiffness to resist the horizontal force defined in section 3.2.1 of the CTE's Structural Safety document: Actions in Building (DB SE-AE, 2009), based on the building's use category.

Section 3.2 of DB SE-AE indicates that railings, parapets, or guards on terraces, balconies, or stairs must resist a uniformly distributed horizontal force whose characteristic value depends on the building use category. This force must be applied at 1.2 m height or at the top edge if lower. Table 1 reproduces the information from the DB SE-AE.

TABLE I
LOADS ON RAILINGS AND OTHER DIVIDING ELEMENTS (DB SE AE)

Categories of use	Horizontal Force (kN/m)
C5	3.0
C3, C4, E, F	1.6
Remaining cases	0.8

TABLE II
CATEGORIES OF USE (DB SE AE)

Categories of use	
A	Residential areas
B	Administrative areas
C	Public access areas (except those belonging to categories A, B and D)
C3	Areas without obstacles that impede the free movement of people, such as lobbies of public buildings, administrative buildings, hotels, museum exhibition halls, etc.
C4	Areas designated for gym or physical activities
C5	Crowded areas (concert halls, stadiums, etc.)
D	Commercial areas
E	Traffic and parking areas for light vehicles (total weight < 30kN)
F	Roof decks accessible only privately
G	Roofs accessible only for maintenance purposes

Additionally, if barriers are placed in front of fixed seating rows, the height may be reduced to 70 cm if a horizontal element of at least 50 cm width is included at a minimum height of 50 cm. In this case, the barrier must resist a 3 kN/m horizontal force at the top edge and a simultaneous uniform vertical load of 1.0 kN/m on the outer edge (Fig. 3).

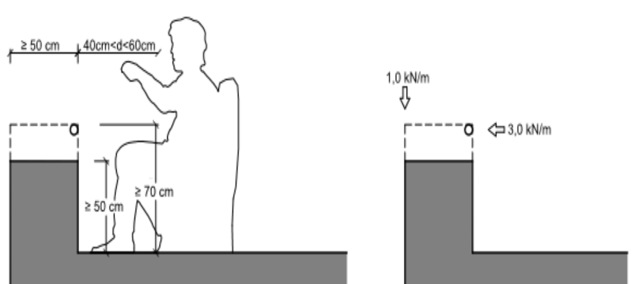

Fig. 3. Measurement of the height of the protective railing on stairs (DB SUA).

III. DESIGN OF GUARDRAILS IN THE UNITED STATES

In the United States (USA), guardrails are typically designed based on criteria specified in the International Building Code (IBC) and/or OSHA standards. Occasionally, local codes or governmental regulatory agency requirements are also applied.

- Most of the reviewed documents specify a minimum guardrail height of 1067 mm ± 3 mm (42 inches ± 3 inches).
- Design loads usually include uniformly distributed loads and point loads.
- Uniform loads simulate the pressure exerted by a group of individuals leaning against the guardrail, typically acting in a horizontal direction. These loads range from 292 N/m to 730 N/m (20 to 50 pounds per foot), depending on the code.
- Point loads represent the force of an individual either leaning on or impacting the guardrail due to a fall. Most U.S. codes and agencies specify this load as 890 N (200 pounds), applied at the most unfavorable location and position.
- Guardrail systems are designed to withstand both uniform and point loads, but not simultaneously.

The IBC is a building code that defines the minimum requirements guardrails must meet in buildings. While local codes may deviate from the IBC, they must not be less stringent. Section 1015 of the IBC outlines the required specifications, summarized as follows:

- Guardrails must be installed when there is a fall risk greater than 762 mm (30 inches).
- Minimum guardrail height: 1067 mm (42 inches).
- Opening limitations: Openings must not permit the passage of a 101.6 mm (4 inches) diameter sphere.
- Resistance requirements: Guardrails must withstand a uniformly distributed load of 730 N/m (50 pounds per foot) at the top edge, as well as a point load of 890 N applied in any direction at any location. These loads are not applied concurrently.

IV. COMPARISON BETWEEN U.S. AND SPANISH REGULATIONS

Despite the fact that guardrails serve the same safety purpose in both countries, the regulatory requirements differ significantly. The differences are analyzed in three key areas: (i) the mandatory installation of guardrails, (ii) geometric requirements, and (iii) mechanical requirements.

i. Mandatory installation of guardrails: In Spain, guardrails are required when the level difference exceeds 55 cm. In the United States, this threshold increases to 76 cm.
ii. Guardrail height: In Spain, the required height ranges from 90 to 110 cm depending on the level difference. In the United States, a minimum height of 107 cm is required regardless of the situation.
iii. Guardrail resistance: In Spain, the regulation mandates a uniformly distributed horizontal load, which varies between 0.8 and 3.0 kN/m depending on the building's use. In the United States, guardrails must be designed for two types of loads: a uniformly distributed load of 730 N/m and a point load of 0.89 kN.

V. CASE STUDY

To assess the extent of the differences between IBC and CTE requirements, a case study is conducted. The simplest configuration is analyzed: a steel guardrail composed of two posts and a top horizontal rail. This choice allows a clear evaluation of the conceptual aspects without complicating the analysis with more complex mechanical calculations.

To calculate a guardrail, a safety format must be selected, including the calculation method (limit states or allowable stresses), load combinations, and safety factors.
The IBC does not specify a particular safety format, and the CTE documents are also ambiguous. However, it is generally accepted, and standard practice, to use the safety format commonly applied in each country for structural calculations, depending on the material used.

For the U.S., calculations follow the American Institute of Steel Construction (AISC, 2022) procedure, based on Load and Resistance Factor Design (LRFD). Loads are factored by 1.6, and material strength is reduced by multiplying the yield stress by 0.9.

For Spain, calculations use the Structural Code issued by the Ministry of Transport and Sustainable Mobility (2021), and load factors are taken from the CTE's Basic Document on Structural Safety (2019). Loads are increased by 1.5 and material strength is reduced by dividing the yield stress by 1.05.

The model considers two posts fully fixed at the base and a beam (guardrail) simply supported between them. González et al. (2011) validated this model in previous resistance studies. Though not suitable for stiffness assessments due to the idealized fixed base assumption, it is valid since neither code imposes displacement checks.

For the U.S. code, two separate load cases are applied: a uniformly distributed horizontal load along the guardrail and a horizontal point load at midspan (worst-case scenario).

For Spain, only a uniformly distributed horizontal load is considered, applied similarly.

The guardrail is modeled as a simply supported beam, with supports at the post connections. Each post is modeled as a cantilever subjected to the reaction force from the beam. For worst-case evaluation, the point load is assumed to act directly on the top of the post.

In both cases, the required bending moment capacity is determined for the post and guardrail sections. A rectangular hollow section is selected for the posts, and a circular hollow section for the guardrail.

Table 3 and 4 summarize the calculation results for the guardrail and the post, respectively, under both regulations. The first column of the tables specifies the type of load used, uniform or point load; the second column indicates the regulations used, Spanish or American; columns 3-5 contain information on the actions, unincreased load in column 3, load increase coefficient in column 4 and increased load in column 5; columns 6-8 show the results of the material strength, steel elastic limit in column 6, strength reduction coefficient in column 7 and design strength of the material in column 8; Finally, columns 9-11 contain the calculation of the stresses and the result obtained as the necessary section of railing or post. Column 9 indicates the calculation moment, column 10 shows the resistant moment that the section must have to withstand the calculation moment, and column 11 gives the solution that has the resistant moment from the previous column.

If we analyse the results obtained for the railing and the post, we can see that when the analysis is performed using uniformly distributed load, the Spanish and US standards lead to the same result because the differences in the load values to be used are almost perfectly offset by the coefficients used

TABLE III
RAILING CALCULATIONS

Load type	Country	Actions			Resistance			Calculation		
		Load q_0 (kN/m)	Inc. Coef. γ_f	Inc. Load q_d (kN/m)	Elast. Lim. f_y (MPa)	Min. Coef. γ_s	Cal. Res. f_{yd} (MPa)	Calc. Moment. M_d (kN·m)	Req. resist. W_n (mm^3)	Solution
Distributed load				$q_d = \gamma_f \cdot q_0$			$f_{yd} = \frac{f_y}{\gamma_s}$	$M_d = \frac{q_d \cdot L^2}{8}$	$W_n = \frac{M_d}{f_{yd}}$	$W_{pl} \geq W_n$
	Spain	0.8	1.5	1.2	275	1.05	262	0.73	2771	**33.7x3.2**
	USA	0.73	1.6	1.2	275	1.11	248	0.73	2944	**33.7x3.2**
		Q_0 (kN)	γ_f	Q_d (kN)	f_y (MPa)	γ_s	f_{yd} (MPa)	M_d (kN·m)	W_n (mm^3)	
Punctual Load				$Q_d = \gamma_f \cdot Q_0$			$f_{yd} = \frac{f_y}{\gamma_s}$	$M_d = \frac{Q_d \cdot L}{4}$	$W_n = \frac{M_d}{f_{yd}}$	$W_{pl} \geq W_n$
	USA	0.89	1.6	1.4	275	1.11	248	0.78	3158	**33.7x4.0**

TABLE IV
POLE CALCULATIONS

Load type	Country	Actions			Resistance			Calculation		
		Load P_0 (kN)	Inc. Coef. γ_f	Inc. Load q_d (kN/m)	Elast. Lim. f_y (MPa)	Min. Coef. γ_s	Cal. Res. f_{yd} (MPa)	Calc. Moment. M_d (kN)	Req. resist. W_n (mm^3)	Solution
Distributed load		$P_0 = q_0 \cdot L/2$		$P_d = \gamma_f \cdot P_0$			$f_{yd} = \frac{f_y}{\gamma_s}$	$M_d = P_d \cdot L$	$W_n = \frac{M_d}{f_{yd}}$	$W_{pl} \geq W_n$
	Spain	0.88	1.5	1.3	275	1.05	262	1.5	5542	**50x30x2.5**
	USA	0.80	1.6	1.3	275	1.11	248	1.5	5542	**50x30x2.5**
		Q_0 (kN)	γ_f	Q_d (kN)	f_y (MPa)	γ_s	f_{yd} (MPa)	M_d (kN·m)	W_n (mm^3)	
Punctual Load				$Q_d = \gamma_f \cdot Q_0$			$f_{yd} = \frac{f_y}{\gamma_s}$	$M_d = Q_d \cdot L$	$W_n = \frac{M_d}{f_{yd}}$	$W_{pl} \geq W_n$
	USA	0.89	1.6	1.4	275	1.11	248	1.6	6316	**50x30x3.0**

in the calculation. However, when calculating the railing for point load, the calculation in the USA requires the use of a larger profile. Whether the dimensioning must be carried out with uniformly distributed load or point load depends on the length of the railing. The longer the railing, the more weight the distributed load takes on over the point load. For lengths greater than 2.44 m, the dimensioning of steel railings must be carried out for uniformly distributed load, while for shorter lengths, the dimensioning is carried out for point load. This means that for railing spans of less than 2.44 m, the US dimensioning method is more demanding than the Spanish method, and for spans greater than 2.44 m, the same result is obtained.

VI. CONCLUSIONS

This study compares the design procedures for permanent guardrails in Spain and the United States, leading to the following conclusions:

i) Significant differences exist between the requirements in both countries, despite addressing the same risk.
ii) U.S. regulations include a point load verification does not present in the Spanish regulations.
iii) For steel guardrails with spans less than 2.44 meters, the most critical load condition is the point load. As a result, guardrails designed under U.S. standards for spans under 2.44 meters require larger sections than those calculated under Spanish standards.
iv) For guardrails with spans exceeding 2.44 meters, both regulatory systems yield similar design outcomes.

This study focuses on a specific configuration in terms of geometry and materials. Future research should extend the analysis to more complex configurations and alternative materials. Additionally, introducing a mechanical requirement for limiting displacement—similar to provisional guardrails—should be considered.

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