XXXVII IAHS – Study of Temporary Edge Protection Systems using different standards

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Abstract
The risk of fall in height represents the major cause of accidents in the construction sector, both nationally and internationally. One of the most effective measures to prevent this risk is the use of Temporary Edge Protection Systems (TEPS).
Nevertheless, it results significant that the regulations governing this type of protection differs considerably from country to country both in the geometric and mechanical requirements.
In this paper, after a review of international standards relating to TEPS have been obtained analytically the dimensions of TEPS using the most significant standards comparing the obtained results.

1 Introduction

The construction sector has identified as one of the most hazardous industries in the world, and height falls have proved to be the most common cause of fatal injury in the construction industry.[1,2,3] Work at height involves important risk of alls which workers must be protected. Both nationally and internationally, the standards and regulations limit the height of the fall.[4,5,6,7]
In order to prevent the risk of height falls, the strategy to be followed [8,9] refers firstly to the need to eliminate risk at the origin, through the construction work planning, integrating the protection within the structure or installing collective protections to avoid falls. If this is not possible, the height fall is limited using collective protections, which are normally systems formed by nets transmitting the impact energy to the construction structure through more rigid elements, mainly of metal.
The use of guardrails or temporary edge protection systems as protection against falling height represents an appropriate means which eliminates the risk at the origin, avoiding the fall and preventing the possibility of suffering damages when a worker impacts against a system which only limits the fall height. They are an excellent collective protection whose primary function is to prevent falls.

Most of the consulted standards provide the geometric and mechanical requirements for guardrails. The purpose of a guardrail is to support a person leaning on the protection or provide a handhold when walking beside it and arrest a person who is walking or falling towards the protection. This purpose is common in all standards but, the resistance requirements differ significantly from ones standards to others.
The forces on the guardrails are dynamic load, but the standards specified for evaluation equivalent static loads.

2 Objectives

The objectives of this study were:

- To compare the resistance requirements for guardrails required by the international standards.
- To obtain the strict dimensions for guardrails calculated with the requirements of the previous standards.

3 Standards used

3.1 European Standard. EN 13374 Temporary edge protection systems - Product specification, test methods. [10]

Calculations have to be carried out following the Limit State method, using the European standards for the structure engineering. For steel elements, ENV 1993-1-1 – Eurocode 3 (1993) has been followed.
Three situations have been analyzed: Ultimate Limit State (ULS), Service Limit State (SLS) and accidental load.
For ULS, edge protection systems and each of the components, except the toeboard, have to be designed to support a FH1 = 0.30 kN load applied perpendicularly to the post axis. The toeboards shall be capable of supporting a FH2 = 0.20 kN load. These loads should be applied at the two most unfavourable points. When this requirement is fulfilled, it is implies that $M_{Sd} \leq M_{Rd}$ where M_{Sd} is the flexural moment acting on the studied section and M_{Rd} is the moment capable of resisting the section.
At the limit state, an γ_F action increase coefficient of 1.5 should be used, and a decrease factor of the material strength γ_M of 1.1 for metal elements.
To meet the SLS standard, the deflection of the whole system to which the F_{T1} of 0.30 kN load is applied should be greater than 55 mm. For the toeboard, the load to be applied F_{T2} is of 0.20 kN.
Regarding the study of accidental loads, the standards say that the principal guardrail, the intermediate guardrail and the toeboard should support a gravitatory precise strength of F_D = 1.25 kN. This load should be applied in the most unfavourable position of the TEPS, at a 10º inclined sector from the vertical. Compliance of this requirement should be established as in the analogous case of the ULS.
For the assessment of SLS and the accidental loads, the action increase coefficients and the strength decrease coefficients of the materials take the unit value.

3.2 RSST (2001). Règlement sur la santé et la sécurité du travail. Éditeur officiel du Québec. Québec. Canadá. (Regulation on the health and safety of labor. Official Editor of Quebec. Quebec. Canadá). [11]

Resistance Requirements:
A guardrail shall be designed to:

- Resist a concentrated horizontal force of 550 N applied to any point of the top plate.
- Resist a vertical load of 1500 N by linear meter, applied to top plate.

3.3 S-2.1, r.6, 2001. Québec Safety Code for the Construction Industry. Les Publictions du Québec, Gouvernement du Québec, Québec. Canadá. [12]

3.8.2. Resistance
A guardrail shall be designed to:

- Resist a concentrated horizontal force of 900 N applied to any point of the top plate.
- Resist a concentrated vertical force of 450 N applied to any point of the top plate.

3.4 OSHA, 1998. Part 1926 Subpart M CFR 1926.502 Fall Protection systems criteria and practices. Occupational Safey & Healt Administration. US Department of Labor, Washington, DC. [13]

Guardrails systems shall be capable of withstanding, without failure, a force of a least 200 pounds (890 N) applied within 2 inches (5.1 cm) of the top edge, in any outward or downward direction, at any point along the top edge.

3.5 Australian Standard. AS 1657-1992. Fixed platforms, walkways, stairways and ladders - Design, construction and installation. [14]

A post shall be designed to resist a concentrated horizontal force of 550 N applied to any point.
A guardrail shall be designed to resist non-simultaneous forces applied horizontally and vertically to the guardrail:

- 550 N acting vertically or horizontally and
- 330 N per linear metre vertically or horizontally.

4 Calculation models used

The calculation model adopted for the analytical assessment are the following: the guardrails have been considered as beams resting on two points, being the supporting points the intersection with the posts; the post has been considered as a bracket fitted in the slab.
For the calculation of the system, elements have been separately studied incorporating for the analysis of each one of them the effects produced by the others.
The analysis in ULS is identical for the principal and intermediate guardrail. The most unfavourable situation for these elements is produced when the load is placed at the centre of the guardrail, resulting in the maximum deflecting moment of the bar.
For the post, the most unfavourable situation is produced when the load is applied on its cantilevered edge and the most unfavourable section is the base, where the maximum deflection moment and the maximum shear stress is produced (figure 1).
For the calculations in SLS the horizontal movement of the system has been obtained as the addition of the guardrail deflection loaded at the centre of the span and the post deflection. Deflection at the post has been calculated with an action which is half the guardrail load and applied on the edge (figure 2). It has been proved that the deflection at the principal guardrail is greater than the deflection at the intermediate one.

The calculation for accidental actions at the guardrail follows the same methodology as the calculation process in ULS, applying a vertical load of 1.25 kN at the most unfavourable position and using as increase coefficients or decrease coefficients of material strength the unit value.

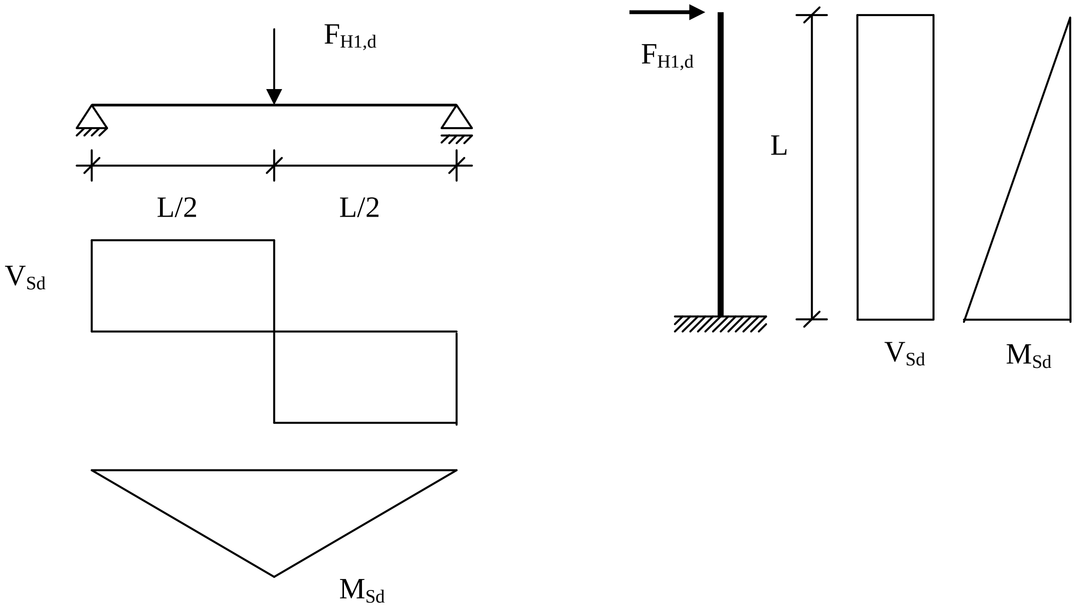

Figure 1: Calculation model for the guardrails and the post.

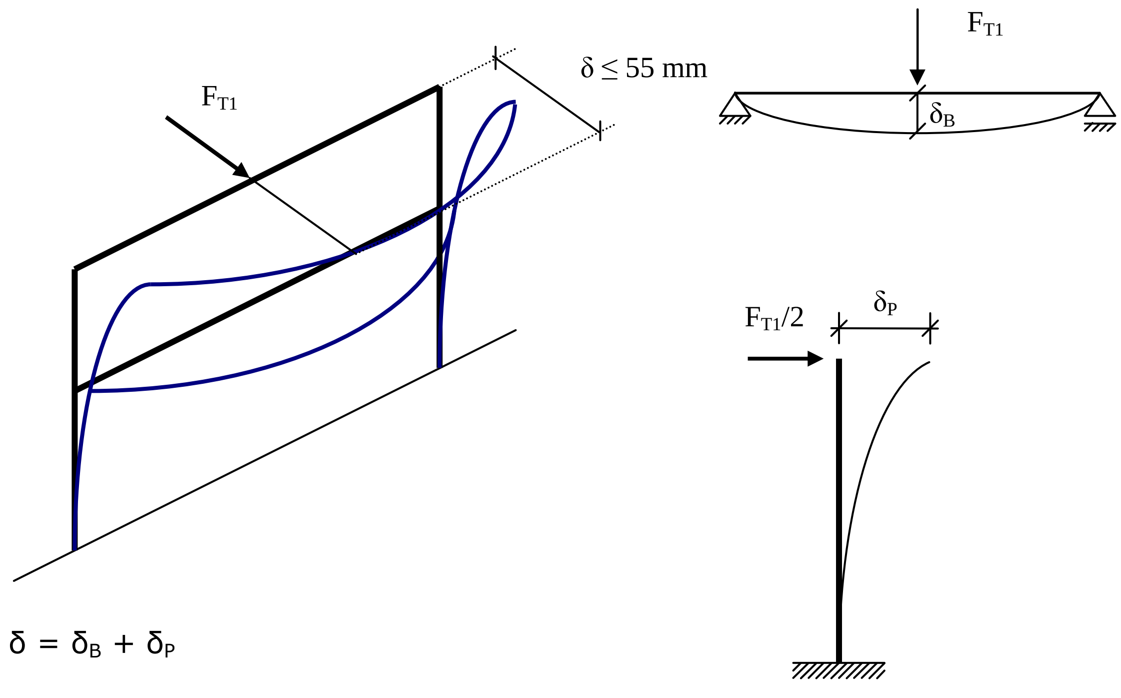

Figure 2: Calculating the system deflection.

5 Results obtained and analysis

Table 1: Show a summary of the results calculation for TEPS using the previous standards.

	EN-13374	RSST (2001)	S-2.1, r.6, 2001	OSHA, 1998	AS 1657-1992
Principal guardrail	○ 42.4 · 2.0 $W_{pl} \geq 3.19$ cm^3	○ 48.3 · 2.5 $W_{pl} \geq 5.06$ cm^3	○ 48.3 · 2.0 $W_{pl} \geq 3.79$ cm^3	○ 42.4 · 2.0 $W_{pl} \geq 2.50$ cm^3	○ 33.7 · 2.0 $W_{pl} \geq 1.54$ cm^3
Post	○ 33.7 · 2.5 $W_{pl} \geq$ 2.11 cm^3	○ 42.4 · 2.0 $W_{pl} \geq 2.57$ cm^3	○ 48.3 · 2.0 $W_{pl} \geq 4.21$ cm^3	○ 48.3 · 2.0 $W_{pl} \geq 4.17$ cm^3	○ 42.4 · 2.0 $W_{pl} \geq 2.57$ cm^3

As it parts with the analysis of the point 3 of this work, the exposition of the analyzed standards defers considerably from some to others.
In all the cases there are specified static loads (the standard EN-13374 uses dynamic loads for TEPS placed in forged with a superior inclination to 10 º), but they differ in the value of the load, the type of load (concentrated or distributed), the simultaneity of different types of loads and the exigency of verifying the displacement.
For the principal guardrail, the most demanding regulation is the RSST (2001) that implies the utilization of a circular pipe 48.3 · 2.5 ($W_{pl} \geq 5.25$ cm^3) due to the uniform load of 1.50 kN/m.
For the post, the most demanding regulation is S-2.1, r.6, 2001 that there implies the utilization of a circular pipe 48.3 · 2.0 ($W_{pl} \geq 4.29$ cm^3) due to a concentrated load of 0.9 kN.

6 Conclusions

- There exist significant differences between the mechanical requirements demanded by different standards and regulations to TEPS.
- Evaluating analytical the principal rail the opposing solutions using different standards, changes from the pipe 48.3 · 2.5 ($W_{pl} \geq 5.25$ cm^3) up to the pipe 33.7 · 2.0 ($W_{pl} \geq 2.01$ cm^3). For the post this interval ranges between the pipe 33.7 · 2.5 ($W_{pl} \geq 2.44$ cm^3) up to the pipe 48.3 · 2.0 ($W_{pl} \geq 4.29$ cm^3).
- Only it is required a checking displacement in the standard EN-13374, when this criterion is basic to assure the safety of the workers.

Reference

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